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*भारतीय मानक*

# उच्च-वोल्टता के लिए स्विच — विशिष्टि

## भाग 2 52 कि वो और उससे अधिक की रेटित वोल्टेज़ के लिए उच्च-वोल्टेज़ के स्विच

*( पहला पुनरीक्षण )*

*Indian Standard*

# HIGH–VOLTAGE SWITCHES — SPECIFICATION

## PART 2 HIGH–VOLTAGE SWITCHES FOR RATED VOLTAGES OF 52 kV AND ABOVE

*( First Revision )*

ICS 29.130.10

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**BUREAU OF INDIAN STANDARDS**
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## NATIONAL FOREWORD

This Indian Standard ( Part 2 ) ( First Revision ) which is identical with IEC 265-2 ( 1988 ) ( renumbered as IEC 60265-2 )'High-voltage switches — Part 2 : High-voltage switches for rated voltages of 52 kV and above' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of High-Voltage Switchgear and Controlgear Sectional Committee and approval of the Electrotechnical Division Council.

First series of standard on switches and switch isolators was published in four parts as follows:

| | |
|---|---|
| IS 9920 ( Part 1 ) : 1981 | Switches and switch isolators for voltages above 1 000 V : Part 1 General and definitions |
| IS 9920 ( Part 2 ) : 1982 | Switches and switch isolators for voltages above 1 000 V : Part 2 Rating |
| IS 9920 ( Part 3 ) : 1982 | Switches and switch isolators for voltages above 1 000 V : Part 3 Design and construction |
| IS 9920 ( Part 4 ) : 1985 | Switches and switch isolators for voltages above 1 000 V : Part 4 Type tests and routine tests |

In the first revision of these standards text has been completely aligned with the corresponding IEC standard and is being published in dual number. With the publication of this new series, which is in two parts, Part 3 and Part 4 of IS 9920 shall be withdrawn.

In this adopted standard, Amendments 1 and 2 issued by IEC have also been printed at the end.

In the adopted standard certain terminology and conventions are not identical to those used in Indian Standards. Attention is especially drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma ( , ) has been used as a decimal marker while in Indian Standards, the current practice is to use a point ( . ) as the decimal marker.

Only the English language text of the International Standard has been retained while adopting it in this Indian Standard.

In this adopted standard, reference ( normative ) appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

| *International Standard* | *Corresponding Indian Standard* | *Degree of Equivalence* |
|---|---|---|
| IEC 50 (441)(1984) International Electrotechnical Vocabulary (IEV), Chapter 441: Switchgear, controlgear and fuses | IS 1885 ( Part 17 ) : 1979 Electrotechnical vocabulary: Part 17 Switchgear and controlgear ( *first revision* ) | Equivalent |
| IEC 56 (1987) High-voltage alternating-current circuit breakers | IS 13118 : 1991 High voltage alternating-current circuit breakers | Identical |

( *Continued on third cover* )

*Indian Standard*

# HIGH–VOLTAGE SWITCHES — SPECIFICATION

## PART 2 HIGH–VOLTAGE SWITCHES FOR RATED VOLTAGES OF 52 kV AND ABOVE

*( First Revision )*

## 1. Scope

This standard is applicable to three-phase alternating-current switches, having making and breaking current ratings, for indoor and outdoor installations, for rated voltages 52 kV and above; and for rated frequencies up to and including 60 Hz.

This standard is also applicable to the operating devices of these switches and to their auxiliary equipment.

*Notes 1.* – Switches for gas insulated switchgear are covered by this standard.

*2.* – Switches having a disconnecting function and called switch-disconnectors are also covered by IEC Publication 129.

*3.* – Earthing switches are not covered by this standard. Earthing switches forming an integral part of a switch are covered by IEC Publication 129.

### 1.101 *Object*

The main object of this standard is to establish requirements for switches used in transmission and distribution systems. General-purpose switches for this application shall comply with the following service applications:

- carrying rated normal current continuously;
- carrying short-circuit currents for a specified time;
- switching of mainly active loads;
- switching of no-load transformers;
- switching of the charging current of unloaded cables, overhead lines or busbars;
- switching of closed-loop circuits;
- making short-circuit currents.

A further object of this standard is to establish requirements for limited-purpose and special-purpose switches used in transmission and distribution systems.

Limited-purpose switches shall comply with one or more of the service applications indicated above.

Special-purpose switches may comply with one or more of the service applications indicated above and, in addition, shall be suitable for one or more of the following applications:

- switching single capacitor banks;
- switching back-to-back capacitor banks;
- switching shunt reactors including secondary or tertiary reactors switched from the primary side of the transformer;
- applications requiring an increased number of operating cycles;
- switching under earth fault conditions in systems with isolated neutral or in resonant earthed systems.

## 2. Normal and special service conditions

IEC Publication 694 is applicable.

## 3. Definitions

For the definitions of general terms used in this standard, reference is made to the IEC Publications 50 (441) and 71-1.

3.101 *Switch* (441-14-10)

A switching device capable of making, carrying and breaking currents under normal circuit conditions, which may include specified operating overload conditions and also carrying for a specified time currents under specified abnormal circuit conditions, such as those of short-circuit.

3.102 *Switch-disconnector* (441-14-12)

A switch which, in the open position, satisfies the isolating requirements specified for a disconnector.

3.103 *General-purpose switch*

A switch capable of performing, with currents up to its rated breaking currents, all making and breaking operations which may normally occur. The switch shall also be capable of carrying and making short-circuit currents.

*Note.* – Refer to Sub-clause 4.114 for specific ratings of a general-purpose switch.

3.104 *Limited-purpose switch*

A switch which complies with one or more, but not with all, service applications of a general-purpose switch.

3.105 *Special-purpose switch*

A switch suitable for switching requirements other than those specified for a general-purpose switch.

*Note.* – Examples of such requirements are capacitor bank switching, shunt reactor switching, switching under earth fault conditions, and a capability of an increased number of operating cycles.

3.106 *Single capacitor bank switch*

A special-purpose switch intended for switching of a single capacitor bank with charging currents up to its rated single capacitor bank breaking current.

3.107 *Back-to-back capacitor bank switch*

A special-purpose switch intended for breaking capacitor bank-charging currents, with one or more capacitor banks connected to the bus or supply side of the switch, up to its rated back-to-back capacitor bank breaking current. The switch shall be capable of making the associated inrush current, up to its rated capacitor bank inrush making current.

3.108 *Shunt reactor switch*

A special-purpose switch intended for switching a shunt reactor, including secondary or tertiary reactors switched from the primary side of the transformer.

3.109 *Breaking capacity** (441-17-08)

3.110 *Mainly active load breaking capacity*

The breaking capacity when opening a mainly active load circuit in which the load can be represented by resistors and reactors in parallel.

3.111 *No-load transformer breaking capacity*

The breaking capacity when opening a no-load transformer circuit.

3.112 *Closed-loop breaking capacity*

The breaking capacity when opening a closed transmission line loop circuit, or a transformer in parallel with one or more transformers, i. e., a circuit in which both sides of the switch remain energized after breaking, and in which the voltage appearing across the terminals is substantially less than the system voltage.

3.113 *Cable-charging breaking capacity*

The breaking capacity when opening a cable circuit at no load.

3.114 *Line-charging breaking capacity*

The breaking capacity when opening an overhead line circuit at no load.

3.115 *Busbar charging breaking capacity*

The breaking capacity when opening a busbar circuit at no load.

3.116 *Single capacitor bank breaking capacity*

The breaking capacity when opening a single capacitor bank circuit connected to a supply that does not include another capacitor bank adjacent to the bank being switched.

3.117 *Back-to-back capacitor bank breaking capacity*

The breaking capacity when opening a capacitor bank circuit connected to a supply that includes one or more capacitor banks adjacent to the bank being switched.

3.118 *Capacitor bank inrush making current*

The high frequency and high magnitude current occurring when closing a capacitor bank circuit onto a supply including one or more capacitor banks adjacent to the bank being switched.

*Note.* – The frequency and magnitude of the inrush current depend upon the values of capacitance and the values of the inductance between the capacitor banks.

3.119 *Shunt reactor breaking capacity*

The breaking capacity when opening a shunt reactor circuit, including secondary or tertiary reactors switched from the primary side of the transformer.

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* *Note concerning the rated values:*
In English, the terms "rated making current" and "rated breaking current" are being used where formerly "rated making capacity" and "rated breaking capacity" were used, the intended meaning being adequately conveyed by the use of "rated". In French, the terms "pouvoir de fermeture assigné" and "pouvoir de coupure assigné" continue to be used.

3.120 *Earth-fault breaking capacity*

The breaking capacity in the faulty phase of an isolated neutral or resonant earthed system when clearing an earth fault on an unloaded cable or overhead line on the load side of the switch.

3.121 *Cable and line charging breaking capacity under earth fault conditions*

The breaking capacity in the sound phases of an isolated neutral or resonant earthed system when switching off an unloaded cable or overhead line, with an earth fault on the supply side of the switch.

3.122 *Breaking current* (441-17-07)

3.123 *(Peak)-making current*

The peak value of the first major loop of the current in a pole of a switch during the transient period following the initiation of current during a making operation.

*Notes 1.* – The peak value may differ from one pole to another and from one operation to another as it depends on the instant of current initiation relative to the wave of the applied voltage.

*2.* – Where, for a polyphase circuit, a single value of (peak) making current is referred to, it is, unless otherwise stated, the highest value in any phase.

3.124 *Short-circuit making capacity* (441-17-10)

## 4. **Rating**

Clause 4 of IEC Publication 694 is applicable with the additions and exceptions indicated below.

4.1 *Rated voltage*

Sub-clause 4.1 of IEC Publication 694 is applicable.

4.2 *Rated insulation level*

Sub-clause 4.2 of IEC Publication 694 is applicable.

4.3 *Rated frequency*

Sub-clause 4.3 of IEC Publication 694 is applicable.

4.4 *Rated normal current and temperature rise*

Sub-clause 4.4 of IEC Publication 694 is applicable.

4.5 *Rated short-time withstand current*

Sub-clause 4.5 of IEC Publication 694 is applicable.

4.6 *Rated peak withstand current*

Sub-clause 4.6 of IEC Publication 694 is applicable.

4.7 *Rated duration of short-circuit*

Sub-clause 4.7 of IEC Publication 694 is applicable.

4.8 *Rated supply voltage of closing and opening devices and auxiliary circuits*

Sub-clause 4.8 of IEC Publication 694 is applicable.

4.9 *Rated supply frequency of operating devices and auxiliary circuits*

Sub-clause 4.9 of IEC Publication 694 is applicable.

4.10 *Rated pressure of compressed gas supply for operation*

Sub-clause 4.10 of IEC Publication 694 is applicable.

4.101 *Rated mainly active load-breaking current**

The rated mainly active load-breaking current is the maximum mainly active load current that the switch shall be capable of breaking at its rated voltage.

4.102 *Rated closed-loop breaking current**

The rated closed-loop breaking current is the maximum closed-loop current the switch shall be capable of breaking. Separate ratings for transmission line loop current and parallel transformer current may be assigned.

4.103 *Rated no-load transformer breaking current**

The rated no-load transformer breaking current is the maximum no-load transformer current the switch shall be capable of breaking at its rated voltage.

4.104 *Rated cable-charging breaking current**

The rated cable-charging breaking current is the maximum cable-charging current that the switch shall be capable of breaking at its rated voltage.

4.105 *Rated line-charging breaking current**

The rated line-charging breaking current is the maximum line-charging current that the switch shall be capable of breaking at its rated voltage.

4.106 *Rated single capacitor bank breaking current**

The rated single capacitor bank breaking current is the maximum capacitor bank breaking current that the switch shall be capable of breaking at its rated voltage with no capacitor bank connected to the supply side of the switch adjacent to the bank being switched.

4.107 *Rated back-to-back capacitor bank breaking current**

The rated back-to-back capacitor bank breaking current is the maximum capacitor bank breaking current that the switch shall be capable of breaking at its rated voltage with one or more capacitor banks connected on the supply side of the switch adjacent to the bank being switched, such as to produce the rated capacitor bank inrush making current.

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* *Note concerning the rated values:*
In English, the terms "rated making current" and "rated breaking current" are being used where formerly "rated making capacity" and "rated breaking capacity" were used, the intended meaning being adequately conveyed by the use of "rated". In French, the terms "pouvoir de fermeture assigné" and "pouvoir de coupure assigné" continue to be used.

### 4.108 *Rated capacitor bank inrush making current**

The rated capacitor bank inrush making current is the peak value of the current that the switch shall be capable of making at its rated voltage and with a frequency of the inrush current appropriate to the service conditions.

The assignment of a rated capacitor bank inrush making current is mandatory for switches that have a rated back-to-back capacitor bank breaking current.

*Note.* – The frequency of the inrush current for back-to-back capacitor banks may be in the range of 2 kHz to 30 kHz. The specific values are dependent upon the size and configuration of the capacitor bank being switched, the supply side capacitor bank and the inclusion of limiting impedances, if any.

### 4.109 *Rated shunt reactor breaking current**

The rated shunt reactor breaking current is the maximum shunt reactor current that the switch shall be capable of breaking at its rated voltage.

*Note.* – The minimum shunt reactor breaking current, if other than zero, that the switch is capable of breaking should be specified by the manufacturer.

### 4.110 *Rated short-circuit making current**

The rated short-circuit making current is the maximum peak prospective current that the switch shall be capable of making at its rated voltage.

### 4.111 *Rated earth fault breaking current**

The rated earth fault breaking current, for an isolated neutral or resonant earthed system, is the maximum earth fault current in the faulted phase that the switch shall be capable of breaking at its rated voltage.

*Note.* – The TRV of an isolated neutral system is more severe than the TRV of a resonant earthed system, even if detuned.

### 4.112 *Rated cable and line-charging breaking current under earth fault conditions**

The rated cable and line-charging breaking current under earth fault conditions, for an isolated neutral or resonant earthed system, is the current in the sound phases that the switch shall be capable of breaking at its rated voltage.

*Note.* – The maximum cable and line-charging current under fault conditions is $\sqrt{3}$ times the cable and line charging current occurring in normal conditions. This covers the most severe case, which occurs with individually screened cables.

### 4.113 *Rated mechanical terminal load*

Sub-clause 4.103 of IEC Publication 129 is applicable.

### 4.114 *Co-ordination of rated values for a general-purpose switch*

A general-purpose switch shall have specific ratings for each switching duty as follows:

- rated mainly active load breaking current shall be equal to the rated normal current;
- rated no-load transformer breaking current shall be equal to 1.0% of the rated normal current;

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* *Note concerning the rated values:*
In English, the terms "rated making current" and "rated breaking current" are being used where formerly "rated making capacity" and "rated breaking capacity" were used, the intended meaning being adequately conveyed by the use of "rated". In French, the terms "pouvoir de fermeture assigné" and "pouvoir de coupure assigné" continue to be used.

- rated transmission line loop breaking current shall be equal to the rated normal current;
- rated parallel transformer breaking current shall be equal to 50% of the rated normal current;
- rated cable-charging breaking current shall be as shown in Table I;
- rated line-charging breaking current shall be as shown in Table I;
- the rated short-circuit making current shall be equal to the rated peak withstand current.

The standard values of ratings should be selected from the R10 series specified in IEC Publication 59.

*Notes 1.* – Specific co-ordination between rated normal current and rated voltage is not a requirement of this standard.

2. – Specific co-ordination between rated normal current and short-time withstand current is not a requirement of this standard.

### 4.115 *Co-ordination of rated values for limited-purpose and special-purpose switches*

A limited-purpose switch should preferably have the same specific ratings as those for a general-purpose switch, where such ratings are applicable. If other ratings are specified, values from the R10 series should be selected.

A special-purpose switch is not required to have coordinated ratings. The rated values, however, should be selected from the R10 series specified in IEC Publication 59.

## 5. **Design and construction**

Clause 5 of IEC Publication 694 is applicable with the additions indicated below.

### 5.1 *Requirements for liquids in high-voltage switches*

Sub-clause 5.1 of IEC Publication 694 is applicable.

### 5.2 *Requirements for gases in high-voltage switches*

Sub-clause 5.2 of IEC Publication 694 is applicable.

### 5.3 *Earthing of high-voltage switches*

Sub-clause 5.3 of IEC Publication 694 is applicable.

### 5.4 *Auxiliary equipment*

Sub-clause 5.4 of IEC Publication 694 is applicable.

### 5.5 *Dependent power closing*

Sub-clause 5.5 of IEC Publication 694 is applicable.

### 5.6 *Stored energy closing*

Sub-clause 5.6 of IEC Publication 694 is applicable.

### 5.7 *Operation of releases*

Sub-clause 5.7 of IEC Publication 694 is applicable.

### 5.8 *Low and high pressure interlocking devices*

Sub-clause 5.8 of IEC Publication 694 is applicable.

### 5.9 *Nameplates*

Sub-clause 5.9 of IEC Publication 694 is applicable. Switches and their operating devices shall be provided with nameplates which contain information in accordance with Table II.

### 5.101 *Closing mechanism*

For switches having a short-circuit making current rating, only switches having stored energy closing or dependent power closing mechanisms are allowed.

### 5.102 *Mechanical strength*

Switches shall be capable of bearing the rated mechanical terminal load when installed according to the manufacturer's instructions, as well as electromagnetic forces, without reduction of their reliability or current carrying capacity.

### 5.103 *Position of the movable contact system and its indicating or signalling device*

### 5.103.1 *Securing the position*

Switches, including their operating devices, shall be so constructed that they cannot come out of their open or closed positions by forces arising from gravity, vibration, reasonable shocks or accidental touching of the connecting rods of their operating devices, or by electromagnetic forces. Switches or their operating devices shall be designed to allow the application of means to prevent unauthorized operation.

### 5.103.2 *Indication of position*

The open and closed positions of the switches shall be clearly indicated. This requirement is met if one of the following conditions is fulfilled:

*a)* the gap or isolating distance is visible;

*b)* the position of each movable contact is indicated by a reliable indicating device.

*Notes 1.* – A visible moving contact may serve as the indicating device.

*2.* – In the case where all poles of a switch are so coupled as to be operated as a single unit, it is permissible to use a common indicating device.

### 5.103.3 *Auxiliary contacts for signalling*

Signalling of the closed position shall not take place until it is certain that the movable contacts will reach a position in which the rated normal, peak withstand, and short-time withstand currents can be carried safely.

Signalling of the open position shall not take place until the movable contacts have reached a position such that the corresponding gap or isolating distance is at least 80% of the total isolating distance, or until it is certain that the movable contacts will reach their fully open position.

## 6. **Type tests**

The type tests are for the purpose of proving the characteristics of high-voltage switches, their operating devices and their auxiliary equipment.

Type tests include:

*a)* *normal type tests:*

- dielectric tests including lightning and switching impulse tests, power-frequency voltage withstand tests, and power-frequency voltage withstand tests on auxiliary and control circuits;
- temperature-rise tests;
- measurement of the resistance of the main circuit;
- short-time withstand current and peak withstand current tests;
- tests to prove the ability of the switch to make and break the specified currents;
- tests to prove satisfactory mechanical operation and endurance.

All of the above tests should be made on the complete high-voltage switch (filled with the specified types and quantities of liquid or gas at specified pressure or reduced pressure, as required), and on its operating devices and auxiliary equipment.

The high-voltage switch tested shall conform in all essential details to drawings of the type of switch specified.

*b)* *type tests upon special request of the user:*

- tests to prove the ability of the switch to make or break currents that are specified by the user and are beyond the scope of the normal type tests;
- tests to prove the ability of the switch to interrupt earth faults in systems with isolated neutrals or in resonant earthed systems;
- tests to prove satisfactory operation under severe ice conditions;
- tests to prove the integrity of the external insulation under conditions of air pollution;
- tests to determine the capability of a switch for applications requiring an increased number of operating cycles;
- radio interference voltage (R. I. V.) tests;
- partial discharge tests;
- tests for verification of operation during application of rated mechanical terminal loads.

### 6.1 *Dielectric tests*

Sub-clause 6.1 of IEC Publication 694 is applicable with the following exception:

### 6.1.9 *Partial discharge tests*

Sub-clause 6.1.9 of IEC Publication 694 is replaced by the following:

No partial discharge tests are required to be performed on the complete high voltage switch. However, in the case of switches using components for which a relevant IEC publication exists, including partial discharge measurements (e.g., bushings, IEC Publication 137), evidence shall be produced by the manufacturer showing that these components have passed the partial discharge tests as foreseen by the relevant IEC publication. For partial discharge measurements, refer to IEC Publication 270.

6.2 *Radio interference voltage (RIV) tests*

Radio interference voltage tests shall be performed by agreement between manufacturer and user. Sub-clause 6.2 of IEC Publication 694 is applicable with the following addition:

Tests may be performed on one pole of the switch in both closed and open positions.

*Note.* – These tests are not required for switches with rated voltages 52 kV to 100 kV, nor for switches used in gas-insulated substations.

6.3 *Temperature rise tests*

Sub-clause 6.3 of IEC Publication 694 is applicable.

6.4 *Measurement of the resistance of the main circuit*

Sub-clause 6.4 of IEC Publication 694 is applicable.

6.5 *Short-time withstand current and peak withstand current tests*

Sub-clause 6.5 of IEC Publication 694 is applicable.

6.101 *Making and breaking tests*

6.101.1 *Arrangement of the switch for tests*

The switch under test shall be completely mounted on its own support, or on an equivalent support. Its operating device shall be operated in the manner prescribed and in particular, if it is electrically or pneumatically operated, it shall be operated at the minimum supply voltage or air pressure, respectively.

Before commencing making and breaking tests, no-load operations shall be made, and details of the operating characteristics of the switch, such as speed of travel, closing time, and opening time, shall be recorded.

If applicable, tests shall be performed at the minimum gas density of the gas for interruption.

Switches with manual operation may be operated by remote control or power operating means such that an operating speed equivalent to that of the manual operator is obtained.

Consideration shall be given to the effects of energization of either terminal of the switch. When the switch in service can be supplied or energized from either terminal, and the physical arrangement of one side of the switch differs from that of the other side, the supply side of the test circuit shall be connected to one side so as to represent the most onerous conditions. In case of doubt, part of the breaking and making tests shall be carried out with the supply side of the test circuit connected to one side of the switch and part with the supply connected to the other side.

Making and breaking tests on three-pole switches shall be carried out as follows:

- a three-pole switch having all three poles mounted within a common enclosure shall be tested as a complete unit. Only three-phase making and breaking tests are permitted, unless it can be shown that there is no interaction or communication between poles during making or breaking.
- a three-pole switch consisting of three single-pole switches should be tested as a complete unit. Three-phase making and breaking tests are preferable, but for convenience or due to

laboratory limitations, single-phase tests on one pole of the switch may be performed, provided that it is not in a more favorable condition than the complete three-pole switch over the range of tests with respect to:

- speed of make;
- speed of break;
- power and strength of closing and opening mechanism;
- rigidity of structure.

Where single-phase tests are permitted, unit tests may be performed, provided that the switch satisfies the requirements of Sub-clause 6.102.3.2 of IEC Publication 56.

Single-phase or three-phase synthetic tests may be performed in accordance with Sub-clause 6.102.4 of IEC Publication 56.

For switches normally installed within a metal enclosure, excepting gas-insulated metal-enclosed switches, and having the characteristic of the emission of flame or metallic particles during breaking or making, the following procedure is required. The tests shall be made with the switch mounted within the metal enclosure or with metallic screens placed in the vicinity of the live parts, and separated from them by a clearance which the manufacturer shall specify. The screens, frame and other normally earthed parts shall be connected to earth through a fuse consisting of a copper wire of 0.1 mm diameter and 5 cm in length. No significant leakage is assumed to have occurred if this wire is intact after the test.

### 6.101.2 *Earthing of test circuit and switch*

Breaking tests conducted on general-purpose, three-pole switches, with rated voltages of 170 kV and below, using a three-phase test circuit, shall be performed with either the neutral point of the supply earthed, or the neutral point of the load earthed. In the first case, the zero sequence impedance shall be less than three times the positive sequence impedance on the supply side. In either case, the test circuit and the frame of the switch shall be earthed so that the voltage conditions between live parts and earth and across the switch, after arc extinction, are representative of service voltage conditions.

General-purpose switches, with rated voltages of 245 kV and above, shall be tested using an earthed neutral for both the supply and load circuits.

For single-phase breaking tests on three-pole switches or for tests on single-pole switches, tests shall be performed with one terminal of the pole to be tested connected to the supply, and the other terminal connected to the load. The common-side connection of the load and supply may be earthed, as shown in Figure 2 and Figure 4, for example. (However, when it is necessary to ensure the correct voltage distribution between the units of a multi-unit switch, another point of the supply circuit may be connected to earth.)

For capacitive test circuits, refer to Sub-clause 6.101.8.3 Items *c)* and *d)*.

The connections used in all tests shall be indicated in the test report.

*Note.* – The recommended earthing connections for general-purpose switches are based upon the conditions that, for rated voltages 170 kV and below, the system is unearthed (supply or load or both), and for rated voltages 245 kV and above, the system is earthed (both supply and load). For other earthing conditions, tests for special-purpose or limited-purpose switches are to be conducted and breaking ratings are to be established, by agreement between the manufacturer and user.

6.101.3 *Test frequency*

Switches shall be tested at rated frequency, with a tolerance of ±10%. However, for convenience of testing, some deviations from the above tolerance are allowable; for example, when switches rated at 50 Hz are tested at 60 Hz and vice versa. Care should be exercised in the interpretation of the results, taking into account all significant facts such as the type of switch and the type of test performed.

*Note.* – In some cases, the rated characteristics of a switch may be different for use at 60 Hz than for use at 50 Hz.

6.101.4 *Test voltage for breaking tests*

The test voltage for three-phase tests shall be equal to the rated voltage of the switch except as noted for specific test duties. Test voltages are shown in Table VI.

Single-phase tests may be used as an alternative to three-phase tests for three-pole switches if it can be shown that the conditions of Sub-clause 6.101.1 are met. Switches designed so as to permit operation of each pole irrespective of the state of the other poles may also be tested single-phase.

Three-pole switches may be classified into two categories with respect to pole non-simultaneity. Pole non-simultaneity is the maximum time between the instant of contact separation of the first pole and the last pole. Single-phase tests on switches with 0.5 cycle or less non-simultaneity (0.25 cycle or less for test-duty 4) shall be tested in accordance with the values specified in Table VII A. Switches having a non-simultaneity greater than 0.5 cycle (greater than 0.25 cycle for test-duty 4) shall be tested in accordance with the values specified in Table VII B.

Single-phase tests on switches operated pole after pole shall be conducted in accordance with the values specified in Table VII B.

Non-simultaneity shall be measured using values of supply voltage or pressure of the operating device and gas pressure of the interrupter yielding the maximum non-simultaneity.

The test voltage shall be measured immediately after interruption, with the exception of capacitive loads, wherein the voltage is measured immediately prior to opening of the contacts. The voltage shall be measured as closely as possible to the terminals of the switch, i. e., without appreciable impedance between the measuring point and the terminals. For three-phase tests, the test voltage shall be expressed as the average of the phase-to-phase test voltages. The test voltage between any two phases shall not be different from the average test voltage by more than 10%.

The power frequency test voltage shall be maintained for at least 0.1 s after interruption, for breaking tests. For capacitive circuit-breaking tests, however, the voltage, including the d. c. component, should be maintained for at least 0.3 s.

For unit tests, a reduced test voltage shall be chosen so as to impose the proper voltage on a unit of a multi-unit switch.

6.101.5 *Breaking current*

The current to be interrupted shall be symmetrical with negligible decrement. The contacts of the switch shall not be separated until transient currents due to closing of the circuit have subsided.

The breaking current for three-phase tests shall be the rated current for the specific test duty and is measured as the average of the current interrupted in all poles. The difference between the average current and the values obtained in each pole shall not exceed 10% of the average value.

The breaking currents for three-phase tests and single-phase tests shall be as shown in Table VI and Table VII A or VII B respectively.

The waveform of the test current, for capacitive circuit-breaking tests, should be sinusoidal. This requirement is satisfied if the ratio of the r.m.s. value of the total current to the r.m.s. value of the fundamental component does not exceed 1.2. The test current shall not go through zero more than once per half cycle of power frequency.

The breaking capacity shall be stated in terms of:

*a)* the test voltage;

*b)* the breaking current;

*c)* the circuit power factor;

*d)* the test circuit;

*e)* the transient recovery voltage parameters;

*f)* the number of close-open operating cycles.

### 6.101.6 *Test voltage for short-circuit making tests*

Three-phase tests should preferably be made on three-pole switches at the rated voltage of the switch.

Single-phase tests on a three-pole switch may also be made, provided it can be shown that conditions of Sub-clause 6.101.1 are met. Additionally, it must be shown that the severity of single-phase tests with regard to the mechanical forces produced on each pole and on the operating device are equal to or more severe than those produced during a three-phase test. Test voltages for single-phase tests are shown in Tables VII A and VII B.

Laboratory limitations at the higher voltages may be such as to make direct tests at rated voltage and rated current extremely difficult. A synthetic making circuit may be used under these circumstances so as to produce the required test voltage from one supply and the rated making current from a second supply.

Under certain conditions, tests may be performed at a reduced voltage. It must be shown that reduced voltage tests are not less severe than tests at the proper voltages as indicated in Tables VI, VII A and VII B. A means shall be provided of causing the initiation of arcing on closing at the same distance as that which would be attained at the proper three-phase or single-phase test voltages. There should be no significant distortion or interruption of the making current during the closing period.

### 6.101.7 *Short-circuit making current*

The short-circuit making current shall be expressed as the maximum value of the peak test currents for three-phase tests, or the peak test current for a single-phase test, and shall be at least 100% of the rated short-circuit making current in at least one test of the two tests required. The tests are considered valid if the peak current in the other test is at least 90% of the rated value or of the specified test current. The symmetrical r.m.s. value of current in each pole during the tenth cycle of current shall be at least 80% of the rated short-time withstand current. The duration of the short-circuit current shall be at least 10 cycles.

Due to pre-arcing, it is not always possible to achieve the required rated short-circuit making current even though tests are made at the rated voltage of the switch. For this case, evidence shall be given that the making currents attained are representative of the currents which will be achieved upon application of the switch at rated voltage in a circuit wherein the maximum prospective peak current is equal to the rated short-circuit making current.

The short-circuit making current performance shall be stated in terms of:

*a)* the test voltage;

*b)* the making current expressed as a peak value;

*c)* the r.m.s. value of the a.c. component as measured during the tenth cycle of the test current;

*d)* the short-circuit current duration;

*e)* the test circuit;

*f)* the means used to cause initiation of arcing at the proper distance if tests are made at reduced voltage;

*g)* the number of making operations.

### 6.101.8 *Test circuits for breaking tests*

Breaking tests on three-pole switches may be performed using three-phase test circuits or single-phase test circuits, except as noted in Sub-clause 6.101.1.

### 6.101.8.1 *Mainly active load circuit (test-duty 1 and test-duty 3)*

The test circuits, Figures 1 and 2, consist of a supply circuit and a load circuit.

The supply circuit, representing the total series impedance, shall have series-connected reactance and resistance and shall have a power factor not exceeding 0.2. The impedance of the supply circuit shall be 15% ± 3% of the total impedance of the test circuit for test-duty 1. The same supply circuit impedance may be used for test-duty 3.

The impedance representing the supply side circuit may be connected on the source side of the switch, or split on both sides; provided that the prospective transient recovery voltage shall not be less severe than those specified in Table III. For earthing conditions other than those described in Table III, tests are to be performed upon agreement between manufacturer and user.

The load circuit shall have a power factor between 0.65 and 0.75 and shall consist of reactors and resistors connected in parallel.

### 6.101.8.2 *Closed-loop circuits (test-duty 2)*

*a)* *Transmission line circuit (test-duty 2a)*

The test circuits, Figures 3 and 4, shall have a power factor not exceeding 0.3. The prospective transient recovery voltages shall not be less than those specified in Table IV A.

The open circuit, phase-to-phase, test voltages for three-phase tests on three-pole switches are 20% of rated voltage for switches having rated voltages below 300 kV, and 15% of rated voltage for switches having rated voltages of 300 kV and above. Test voltages for single-phase tests are shown in Tables VII A and VII B.

*Note.* – These values are tentative and are subject to revision.

Unusually long or series compensated transmission lines are considered to be special cases wherein the actual voltages may be higher than those specified. Tests are to be conducted for these applications upon agreement between manufacturer and user.

The prospective transient recovery voltage waveforms specified have the form of a triangular wave due to the surge impedance of the connected transmission lines. A transient recovery voltage having a (1-cos) form may be used, however, for convenience in testing, if the RRRV and $U_c$ values as specified in Table IV A are achieved as evaluated by the 2 parameter method.

*b) Parallel transformer circuit (test-duty 2b)*

The test circuits, Figures 3 and 4, shall have a power factor not exceeding 0.2. The prospective transient recovery voltages shall be not less severe than those specified in Table IVB.

### 6.101.8.3 *Capacitive circuits (test-duty 4)*

*a) General*

Field tests or laboratory tests may be made. For field tests, the actual lines, cables and capacitor banks shall be used. For laboratory tests, the lines or cables may be partly or fully replaced by artificial circuits with lumped elements consisting of capacitors, reactors or resistors.

The use of laboratory test circuits for verification of the rated line or cable-charging breaking current is valid only if the switch is restrike-free. Single-phase tests of a three-pole switch are valid only if the switch is restrike-free and the requirements of Sub-clause 6.101.1 are fulfilled.

If the switch is not restrike-free or if the test plant limitations preclude the use of three-phase tests, a single-phase test using laboratory circuits may be used upon agreement between manufacturer and user. For breaking tests under earth fault conditions, these restrictions are not applicable.

*Notes 1.* – For a restrike-free switch, tests at 60 Hz may be performed to demonstrate the breaking performance at 50 Hz.

*2.* – Where single-phase laboratory tests are permitted for capacitor bank switching, or capacitor banks are used to represent lines or cables, the specification of the circuits may be replaced by specification of the switch recovery voltages, as given in Table VIII and identified in Figure 7.

*3.* – The laboratory test circuits representing lines and cables are not applicable for determining the magnitude of possible overvoltage when restrike occurs. They are adapted to demonstrate the switching performance only.

*4.* – Synthetic test procedures for capacitive current switching are under consideration.

*b) Characteristics of supply circuit*

A supply circuit shall be used having an impedance such that the prospective short-circuit current does not exceed the rated short-time withstand current of the switch. The characteristics of the test circuit shall be such that the voltage variation when switching is as small as possible and is in any case less than 5%. For line-charging, cable-charging or single capacitor bank current breaking tests, the capacitance of the supply circuit shall be as low as possible; however, the prospective transient recovery voltage parameters shall be less severe than the TRV parameters specified in IEC Publication 56 for short circuit test-duty 4. Refer to Sub-clause 6.104.5.2 of IEC Publication 56.

For back-to-back capacitor bank breaking current tests, the capacitance of the supply circuit and the impedance between the capacitors on the supply and load sides shall be such as to give the rated capacitor bank inrush making current when testing with 100% of the rated back-to-back capacitor bank breaking current.

*Notes 1.* – If a switch is intended to be used in a network with appreciable lengths of cable on the supply circuit, appropriate additional capacitance may be used on the supply circuit.

*2.* – For back-to-back capacitor bank current switching tests, with restrike-free switches, and where separate making tests are performed, a lower capacitance of the supply circuit may be chosen for the breaking tests.

*c) Earthing of the supply circuit*

For single-phase laboratory tests, either terminal of the single-phase supply circuit may be earthed. However, when it is necessary to ensure the correct voltage distribution between the units of the switch another point of the supply circuit may be connected to earth.

For three-phase tests, the earthing shall be as follows:

- for capacitor bank current switching tests, the neutral of the supply circuit shall be earthed. The zero sequence impedance shall be less than three times the positive sequence impedance of the supply side;
- for line-charging and cable-charging current switching tests, the earthing of the supply circuit shall, in principle, correspond to the earthing conditions in circuits for which the switch is to be used:
  - for tests of a switch intended for use in earthed neutral systems, the neutral point of the supply circuit shall be earthed. The zero sequence impedance shall be less than three times the positive sequence impedance of the supply side.
  - for tests of a switch intended for use in isolated neutral and resonant earthed systems, the neutral point of the supply side shall be isolated or connected to earth through an arc suppression coil.

*d) General characteristics of the capacitive circuits to be switched*

The earthing of the capacitive circuit to be switched shall be such as to conform to the applications for which the switch is intended. Test voltages as specified in Tables VII A and VIIB are dependent upon the nature of earthing of capacitor bank neutrals and the screening of cables.

The characteristics of the capacitive circuit, with all necessary measuring devices such as voltage dividers included, shall be such that the voltage decay on the switched capacitance does not exceed 10% at the end of an interval of 100 ms after final arc extinction. This requirement does not apply for field tests.

*Note.* – Since the voltage decay may be very much influenced by apparatus such as voltage transformers connected to the capacitive circuit, the measurement should be made with suitable voltage dividers.

*e) Cable-charging circuit (test-duty 4a)*

For restrike-free switches, capacitors may be used to simulate screened and belted cables. For three-phase tests representing three-core belted cables, the capacitance to earth shall be approximately the same as the capacitance between phases.

When capacitors are used to simulate cables, a non-inductive resistance, not exceeding 10% of the capacitive impedance, may be inserted in series with the capacitors. Higher values may unduly influence the recovery voltage. If the peak inrush current is still unacceptably high, then an alternative impedance (e. g., LR), may be used instead of the resistor, provided that the current and voltage conditions at the instant of breaking, and the recovery voltage, do not differ significantly from the specified values (the characteristics of the alternative impedance are under consideration).

*Note.* – A short overhead line may be used in series with the cable for the tests, provided the line-charging current does not exceed 1% of the cable-charging current.

*f) Line-charging circuit (test-duty 4b)*

For restrike-free switches, one or more of the following procedures may be used:

1) Three-phase tests, where it is allowed to use parallel lines or to partly or fully replace the three-phase line by capacitor banks. The resulting positive sequence capacitance shall be approximately twice the zero sequence capacitance.

2) Single-phase tests in a three-phase test circuit, with two phases of the capacitive circuit connected directly to the three-phase supply circuit, and one phase connected to the supply circuit through the switch pole to be tested.
3) Single-phase laboratory tests, where capacitor banks may be used to simulate lines. Where lines are used, any parallel connection of the conductors in the individual phases may be used with a current return through earth or through a conductor.

When capacitors are used to simulate overhead lines, a non-inductive resistance, not exceeding 10% of the capacitive impedance, may be inserted in series with the capacitors. Higher values may unduly influence the recovery voltage. If the peak inrush current is still unacceptably high, then an alternative impedance (e. g., LR) may be used instead of the resistor, provided that the current and voltage conditions at the instant of breaking, and the recovery voltage, do not differ significantly from the specified values (the characteristics of the alternative impedance are under consideration).

*Note.* – A short cable may be used in series with an overhead line for the tests, provided the cable-charging current is less than 20% of the overhead-line charging current.

*g) Busbar charging circuit (test-duty 4c)*

Test circuits are to be selected upon agreement between the manufacturer and user.

*h) Capacitor bank circuits (test duties 4d and 4e)*

For three-phase tests, the neutral of the capacitor bank shall be isolated or earthed, depending upon the rating or use of the switch.

### 6.101.8.4 *Inductive circuits (test-duty 5)*

*a) No-load transformer circuit (test-duty 5a)*

It is recommended that on-site tests be carried out using the specific transformer to be switched for a given installation. Laboratory tests may be carried out using the same transformer, except that the overvoltage magnitudes during switching will not necessarily be valid.

*b) Shunt-reactor circuit (test-duty 5b)*

The load circuit shall consist of a reactor, air-cored or iron-cored, with appropriate shunt capacitance and resistance so as to produce a prospective transient recovery voltage not less severe than the values specified in Table V. A reactor loaded transformer can be used for testing if the proper TRV requirements are met.

The supply-circuit reactance should be less than 10% of the load reactance. The supply-circuit shunt capacitance should be larger than 10 times the load capacitance, but not greater than 20 times.

*Note.* – The overvoltages produced due to reignitions using a laboratory circuit may not necessarily be valid. To achieve representative values, the bus circuits between the switch and supply and the switch and load must be accurately modeled.

Laboratories may have only a limited capability for shunt reactor current breaking tests. It may be necessary, therefore, to perform on-site tests in order to demonstrate performance for a specific installation consisting of a particular reactor and high voltage switch. The TRV conditions may not necessarily conform to the requirements of Table V. These tests may be conducted upon agreement between manufacturer and user. Laboratory tests may also be made using the same reactor, except that the overvoltage magnitudes during switching will not necessarily be valid.

For applications at 245 kV and above, the neutral of a star-connected shunt reactor may be earthed through an additional reactor, for the purpose of permitting single-pole switching of line switches. These applications are special and tests should be performed only upon agreement between manufacturer and user.

### 6.101.9 *Test circuits for short-circuit making tests (test-duty 6)*

The test circuit for a three-phase test on a three-pole switch shall be as shown in Figure 5.

Single-phase tests on three-pole switches or single-pole switches shall use a single-phase test circuit as shown in Figure 6.

### 6.101.10 *Test circuits for breaking tests under earth fault conditions (test-duties 7a and 7b)*

Tests are required only for switches rated below 245 kV. It is assumed throughout this standard that the supply neutral is earthed at rated voltages of 245 kV and above, and that therefore an earth fault at these rated voltages will result in a short-circuit current. For systems other than earthed neutral systems at rated voltages of 245 kV and above, tests are to be made upon agreement between the manufacturer and user.

A single-phase capacitive circuit may be used for breaking tests under earth fault conditions.

Earth fault currents and charging currents under earth fault conditions are capacitive currents. The conditions for performing these tests and the nature of the supply circuits and capacitive circuits to be used, therefore, are identical to those required for capacitive circuits as described in Sub-clause 6.101.8.3. Items *e)* and *f)* within this sub-clause specifically relate to cable and line charging currents. A switch will be required to interrupt these types of currents under earth fault conditions, for both earth fault currents (test-duty 7a) and charging currents under earth fault conditions (test-duty 7b); therefore, the requirements as stated in items *e)* and *f)* should be followed for these tests.

### 6.101.11 *Tests for general-purpose switches*

The required tests for a general-purpose switch are given below. Test-duties 1 through 5 may be performed in any convenient order. The tests shall be performed without reconditioning of the switch during the test program.

Make-break operating cycles shall be carried out for Test-duties 1 through 5. The opening operation shall follow the closing operation with a time delay between the two operations at least sufficient for any transient currents to subside. The breaking currents shall be in accordance with Sub-clause 6.101.5.

The test voltages and currents, and the number of operations for three-phase tests and single-phase tests are given in Tables VI, VII A and VII B, respectively. Tests shall be made at the respective rated breaking currents except as specified in Tables VI, VII A and VII B.

*Test-duty 1 – 100% mainly active load*

Ten make-break operating cycles are required.

*Test-duty 2 – Closed loop*

Test-duty 2a – Transmission circuit – Ten make-break operating cycles are required.

Test-duty 2b – Parallel transformer circuit – Ten make-break operating cycles are required.

*Note.* – If the TRV parameters achieved in test-duty 1 are equal to or more severe than the TRV parameters required for test-duty 2a or 2b, then test-duty 2a or 2b need not be performed.

*Test-duty 3 – 5% mainly active load*

Twenty make-break operating cycles are required. Test-duty 3 is not required for switches having arc extinguishing properties independent of the current magnitude to be interrupted.

*Test-duties 4a and 4b – Cable charging and line charging*

Tests shall be made at 100% and from 20% to 40% of the rated cable and line-charging currents.

The number of make-break operating cycles at each current shall be one of the following:

- ten for three-phase tests;
- thirty for single-phase tests using random contact separation;
- twelve for single-phase tests using controlled contact separation. Contact separation shall be distributed at intervals of approximately 30 electrical degrees.

The overvoltages produced during switching shall preferably not exceed the values suggested in column A of Table IX for general-purpose switches and column A or B for limited-purpose switches as specified by the manufacturer. Refer to Note 3 of Item *a)* of Sub-clause 6.101.8.3.

*Test-duty 4c – Busbar charging circuit*

Tests are to be conducted only upon agreement between the manufacturer and user.

*Notes 1.* – This test duty is normally required for limited-purpose switches only;

*2.* – This switching function is typically performed by disconnectors.

*Test-duty 5a – No-load transformer*

Tests are not normally required for this duty. If tests are required, the number of tests to be performed shall be determined upon agreement between manufacturer and user.

*Test-duty 6 – Short-circuit making*

Short-circuit making tests shall be performed on a switch which has been subjected to at least ten make-break operating cycles at 100% mainly active load as required for test-duty 1. If it can be demonstrated that the short-circuit making performance cannot be affected by the breaking tests specified, then for convenience, test-duty 6 may be performed on a new switch.

Two closing operations are required. The time interval between operations is dependent upon the design features of the switch and the test plant limitations.

### 6.101.12 *Tests for limited-purpose switches*

The tests specified for general-purpose switches shall be used deleting those test-duties for which the switch is not rated.

### 6.101.13 *Tests for special-purpose switches*

Switches having a capability of an increased number of operating cycles, a capacitor bank-breaking current rating, a shunt reactor-breaking current rating, or breaking current ratings under earth fault conditions, shall be tested in accordance with one or more of the following test-duties.

*Test-duty 1 – Increased number of operating cycles for mainly active load*

Special-purpose switches having a capability of an increased number of operating cycles shall be tested according to the specific requirements relating to breaking current and to the number of operations, as agreed between manufacturer and user.

*Test-duties 4d and 4e – Capacitor banks*

Tests shall be made at 100% and from 20% to 40% of the rated capacitor bank breaking current.

The number of make-break operating cycles at each current shall be one of the following:

- ten for three-phase tests;
- thirty for single-phase tests using random contact separation;
- twelve for single-phase tests using controlled contact separation. Contact separation shall be distributed at intervals of approximately 30 electrical degrees.

The making current for back-to-back capacitor bank current switching tests shall be equal to the rated capacitor bank inrush making current.

Due to limitations of the test plant for back-to-back capacitor bank switching tests, it may not be possible to comply with the requirements of inrush current during breaking tests. For restrike-free switches, it is permissible to perform an alternative breaking test procedure wherein the breaking test requirements according to Sub-clause 6.101.8.3 are met to the best possible extent. A separate making test series may then be performed. This test series shall be made with the proper voltage and shall comprise ten making operations with a prospective making current equal to the rated capacitor inrush making current. The making shall occur within 15 electrical degrees of peak voltage.

*Test-duty 5b – Shunt reactor*

Tests shall be made at the maximum rated shunt reactor breaking current. Tests shall also be performed at 20% to 40% of the rated shunt reactor breaking current. If a minimum shunt reactor breaking current is specified, tests shall be performed at the minimum current rather than at 20% to 40% of rated shunt reactor breaking current.

The number of make-break operating cycles at each current shall be one of the following:

- ten for three-phase tests;
- thirty for single-phase tests using random contact separation;
- twelve for single-phase tests using controlled contact separation. Contact separation shall be distributed at intervals of approximately 30 electrical degrees.

*Test-duty 7a – Earth fault current*

Ten make-break operating cycles with the rated earth fault breaking current shall be carried out.

*Test-duty 7b – Cable and line charging current under earth fault conditions*

Ten make-break operating cycles with the rated cable and line charging breaking current under earth fault conditions shall be carried out.

### 6.101.14 *Behaviour of switch during breaking tests*

The switch shall perform successfully without evidence of mechanical or electrical distress. There shall be no flame or material ejected from the switch, or audible noise generated that may be harmful to operating personnel.

There shall be no outward emission of flame or metallic particles from the switch during operation, such as might impair the insulation level of the switch.

There shall be no significant leakage current to the earthed structure or screens, such as to endanger an operator or damage insulation materials.

For all capacitive circuits, test-duty 4, and inductive circuits, test-duty 5, the maximum overvoltages to earth, on the supply or load-circuits, should not be greater than the values suggested in column A or column B of Table IX, as specified by the manufacturer.

### 6.101.15 *Condition of switch after breaking tests*

The mechanical functions and the insulation of the switch shall be essentially in the same condition as before the test. The switch shall be capable of carrying its rated normal current without the temperature rise exceeding the values specified.

The arcing contacts or any other specified renewable parts may be worn. The quality of the oil or other material used for arc extinguishing may be impaired and its amount reduced below the normal level. There may be deposits on the insulators caused by the decomposition of the arc extinguishing medium.

Visual inspection and no-load operation of the switch after tests are usually sufficient for verification of the above requirements. In case of doubt, it may be necessary to perform the appropriate tests for confirmation. If the isolating properties across the open high-voltage switch or to earth are doubted, power-frequency withstand voltage tests at 80% of the rated power-frequency voltages are deemed sufficient to prove the isolating properties.

The isolating properties of a switch-disconnector in the open position shall not be reduced below those specified, by deterioration of insulating parts in the neighbourhood of, or parallel to, the isolating distance. The requirements for disconnectors in IEC Publication 129 shall be fulfilled.

6.101.16 *Condition of switch during and after short-circuit making tests*

No disruptive discharge between energized parts and earth, or between phases, shall have occurred during the test. The switch may sustain damage during the test, which may require maintenance, such as the replacement of parts, renewal of interrupting medium or cleaning and adjustment to restore the switch to its pre-test condition. Before maintenance, the switch shall meet the following criteria:

*a)* mechanical conditions: the switch shall be mechanically operable and, when the opening operation is initiated, it shall open in the intended manner;

*b)* breaking capability: the switch shall be capable of interrupting the rated breaking currents;

*c)* dielectric requirements: the isolating properties across the open high-voltage switch and to earth shall not be reduced below those specified, by deterioration of insulating parts in the neighbourhood of, or parallel to, the isolating distance. In case of doubt, this is deemed to be verified by power-frequency voltage withstand tests at 80% of the rated withstand voltages.

The isolating properties of a switch-disconnector in the open position shall not be reduced below those specified, by deterioration of insulating parts in the neighbourhood of, or parallel to, the isolating distance. The requirements for disconnectors in IEC Publication 129 shall be fulfilled;

*d)* current-carrying capability: the switch shall be capable of carrying its rated current without the stabilized temperature rises of the metallic parts in contact with insulating material exceeding by more than 10 K the maximum values specified. No temperature rise limits apply to other parts of the switch, except that the temperature rise shall reach a stable value.

Visual inspection and no-load operation of the switch after tests are usually sufficient for verification of the above requirements. In case of doubt, it may be necessary to perform the appropriate tests for confirmation.

6.101.17 *Type test reports*

The results of all type tests shall be recorded in type-test reports containing sufficient data to prove compliance with this standard. Sufficient information should be included so that the essential parts of the high voltage switch tested can be identified.

The test report shall contain the information specified in Sub-clauses 6.101.2, 6.101.4, 6.101.5, 6.101.6 and 6.101.7. Typical oscillographic or similar records should be provided, so that the following can be determined:

1) the test currents;

2) the test voltages;

3) the voltages across the terminals of each pole, so that the power frequency recovery voltages and transient recovery voltages may be determined;

4) the voltages to earth, so that overvoltages may be determined, if applicable;

5) if applicable, the instant of energizing the trip coil.

General information concerning the supporting structure of the high-voltage switch should be included. Information regarding the operating devices employed during the tests should, where applicable, be recorded.

### 6.102 *Mechanical operation tests*

### 6.102.1 *Arrangement of the switch for tests*

The switch for test should be mounted on its own support and its operating mechanism shall be operated in the specified manner. It shall be tested according to its type as follows:

- a three-pole switch, with all poles mounted on a common frame, shall be tested as a complete unit;
- a three-pole switch, in which each pole or each column is separately mounted, should be tested as a complete three-pole switch, but for convenience, or owing to the limitations of the dimensions of the test bay, one single-pole unit of the switch may be tested, provided that it is equivalent to, or not in a more favourable condition than, the complete three-pole switch over the range of tests with respect to:
  - speed of closing,
  - speed of opening,
  - power and strength of closing and opening mechanism,
  - rigidity of structure.

When testing of a complete switch pole is not practicable, component tests may be accepted as type tests. Components are separate functional sub-assemblies which can be operated independently of the complete switch (e. g. pole, breaking unit, operating mechanism). The manufacturer should determine the components which are suitable for testing.

When component tests are made, the manufacturer shall prove that the mechanical stress on the component during the tests is not less than the mechanical stress applied to the same component when the complete switch is tested. When component tests are used for type tests as an alternative to the testing of the complete switch, they shall cover all different types of components of the complete switch, provided that the particular test is applicable to the component.

Parts of auxiliary and control equipment which have been manufactured in accordance with the relevant standards, shall comply with such standards. The proper function of such parts in connection with the function of the other parts of the switch shall be verified.

Unless otherwise specified, the tests may be made at any convenient ambient air temperature.

The supply voltage of the operating device shall be measured at the terminals during operation of the switch. Auxiliary equipment forming part of the operating device shall be included. Impedance shall not be added between the supply and the terminals of the device for regulation of the applied voltage.

For manually operated switches, the handle may, for convenience of testing, be replaced by an external power device wherein the operating speed of the switch contacts is equivalent to that for operation with a manual handle.

### 6.102.2 *Tests for general-purpose switches*

The mechanical operation tests shall consist of 1000 operating cycles without voltage on, or current in, the main circuit. If a capability beyond 1000 operating cycles is required, tests should be conducted upon agreement between manufacturer and user.

A switch having a power-operating device shall be subjected to the following tests:

- 900 operating cycles at rated supply voltage and/or rated pressure of compressed gas supply;
- 50 operating cycles at the specified minimum supply voltage and/or minimum pressure of compressed gas supply;
- 50 operating cycles at the specified maximum supply voltage and/or maximum pressure of compressed gas supply.

A manually operated switch shall be subjected to the following test:

- 1000 operating cycles using a range of operating forces typical of that to be expected in service.

No specific time intervals between operating cycles or between closing and opening operations are required. These tests shall be made, however, at a rate such that the temperature rises of the energized electrical control components do not exceed the specified values.

### 6.102.3 *Tests for limited-purpose and special-purpose switches*

Unless otherwise specified, the tests performed shall be in accordance with the tests required for a general-purpose switch. Alternatively, tests may be performed by agreement between manufacturer and user.

### 6.102.4 *Condition of switch during and after mechanical operation tests*

The fully closed and fully open positions shall be attained during each operating cycle.

Satisfactory operation of operating devices, of control and auxiliary contacts, and of position indicating devices (if any), shall be verified during the test.

Lubrication in accordance with the manufacturer's instructions is permissible during the test, but mechanical adjustments are not permitted.

After the tests, all parts shall be in good condition and shall not show excessive wear. The condition of coated contacts shall be such that a layer of coating material remains at the contact area according to the relevant specification for the specific high-voltage switch.

### 6.103 *Operation under severe ice conditions*

If required, tests shall be performed in accordance with Sub-clause 6.103 of IEC Publication 129, with the following exception:

### 6.103.1 *Checking of operation*

The test may be considered satisfactory for switches with a dependent manual operation, even if several attempts are required for successful opening or closing. Switches having stored energy or dependent power operating mechanisms shall operate successfully on the first attempt.

### 6.104 *Verification of operation during application of rated mechanical terminal loads*

The mechanical terminal load test is made only upon agreement between manufacturer and user, and is performed to demonstrate that the high-voltage switch operates correctly when loaded with stresses resulting from ice, wind and connected conductors.

If tests are performed, Sub-clause 6.102.4 of IEC Publication 129 is applicable.

## 7. Routine tests

Clause 7 of IEC Publication 694 is applicable with the following exceptions and additions.

### 7.1 *Power frequency voltage withstand dry tests on the main circuit*

Sub-clause 7.1 of IEC Publication 129 is applicable.

*Note.* – These tests are not required for switch-disconnectors or switches wherein it can be shown that only atmospheric air is used as the insulating medium across the isolating gap when the switch-disconnector or switch is in the open position.

### 7.101 *Mechanical operating tests*

Operating tests are made to ensure that switches comply with the prescribed performance within the specified supply voltage and pressure limits of their operating devices.

During these tests, which are performed without voltage on, or current in, the main circuit, it shall be verified, in particular, that the switches open and close correctly when their operating devices are energized or under pressure. It shall also be verified that operation will not cause any damage to the switches.

The arrangement of the switch for test shall comply with specifications for the mechanical endurance type tests, Sub-clause 6.102.1.

A switch having a power-operating device shall be subjected to the following tests:

- at specified maximum supply voltage and/or maximum pressure of compressed gas supply: five operating cycles;
- at specified minimum supply voltage and/or minimum pressure of compressed gas supply: five operating cycles.

A manually operated switch, or a power-operated switch capable of manual operation, shall be subjected to the following test:

- ten operating cycles.

Routine tests on a complete switch may be made on site.

During these tests, no adjustments shall be made and the operation shall be faultless. The closed and open positions shall be attained during each operating cycle.

## 8. Guide to the selection of high-voltage switches for service

### 8.101 *General*

This guide presents suggestions on application as an aid to obtaining satisfactory performance of high-voltage switches rated at 52 kV and above.

It is offered in recognition of the continuing need for general guidelines to supplement, but not replace, the manufacturer's detailed instructions.

Refer to IEC Publication 694, Sub-clause 2.1 for normal service condition requirements.

### 8.102 *Conditions affecting application*

Where unusual conditions exist, they should be brought to the attention of the manufacturer for his recommendations. Examples of such conditions are:

1) Contamination such as damaging fumes or vapour, excessive or abrasive dust, explosive mixtures of dust or gases, salt spray, excessive moisture or dripping water, etc.

2) Abnormal vibration, shocks, tilting, or seismic activity.
3) Excessively high or low ambient temperatures.
4) Unusual transportation or storage conditions.
5) Unusual space limitations.
6) Mounting positions other than those recommended by the manufacturer.
7) High altitude.
8) Wind velocity in excess of manufacturer's recommendations.
9) Unusual operating duty, frequency of operation, difficulty of maintenance, unbalanced voltages, special insulation requirements, etc.
10) A condition of resonance when switching a capacitor or transformer.
11) For use at other than rated frequency, such as harmonics associated with filter banks, capacitor banks, and rectifier circuits. The normal current rating of the switch should be such as to adequately carry the power frequency current and the harmonic currents.

### 8.103 *Insulation coordination*

The rated insulation level of a switch shall be selected according to Sub-clause 4.2 of IEC Publication 694.

Refer to IEC Publication 71 for a general discussion and recommendations on insulation coordination.

## 9. **Information to be given with enquiries, tenders and orders**

### 9.101 *Information to be given with enquiries and orders*

When enquiring for or ordering a switch, the following particulars should be supplied by the enquirer:

1) *Particulars of system:* i. e., nominal and highest voltages, frequency, number of phases, and details of neutral earthing. Unusual characteristics of system in which the switch is to be applied should be noted (harmonic currents, resonance conditions, number of operations required).
2) *Service conditions* including minimum and maximum ambient air temperatures, if beyond the normal values; altitude, if over 1000 m; and any special conditions likely to exist or arise, e. g. unusual exposure to steam or vapour, moisture, fumes, explosive gases, excessive dust, or salt air (see Sub-clauses 2.1, 2.2 and 6.1.8 of IEC Publication 694 and Sub-clause 8.102 of this standard).

3) *Characteristics of switch*

   The following information should be given:

   *a)* number of poles;

   *b)* type of switch as defined in Clause 3;

   *c)* class: indoor or outdoor;

   *d)* rated voltage (Sub-clause 4.1 of IEC Publication 694);

*e)* rated insulation level where a choice exists between different insulation levels corresponding to a given rated voltage, or, if other than standard, desired insulation level (Sub-clause 4.2 of IEC Publication 694);

*f)* rated frequency (Sub-clause 4.3 of IEC Publication 694);

*g)* rated normal current (Sub-clause 4.4 of IEC Publication 694);

*h)* rated breaking currents as defined in Clause 3 and Clause 4, if applicable;

*i)* if applicable, rated short-circuit making current as defined in Sub-clause 3.124 and Sub-clause 4.110;

*j)* if other than standard, desired duration of short-circuit current (Sub-clause 4.7 of IEC Publication 694);

*k)* the type tests required on special request as defined in Clause 6.

4) *Characteristics of the operating mechanism of switch and associated equipment, in particular:*

*a)* method of operation, whether manual or power;

*b)* number and type of spare auxiliary switches;

*c)* rated supply voltage and rated supply frequency.

5) *Requirements concerning the use of compressed air and requirements for design and test of pressure vessels*

*Note.* – The enquirer should give information pertaining to any special conditions not included above that might influence the tender or order.

9.102 *Information to be given with tenders*

When the enquirer requests technical particulars of a switch, the following information, where applicable, should be given by the manufacturer, with the descriptive matter and drawings:

1) *Rated values and characteristics*

*a)* number of poles;

*b)* type of switch as defined in Clause 3;

*c)* class: indoor or outdoor;

*d)* rated voltage (Sub-clause 4.1 of IEC Publication 694);

*e)* rated insulation level (Sub-clause 4.2 of IEC Publication 694);

*f)* rated frequency (Sub-clause 4.3 of IEC Publication 694);

*g)* rated normal current (Sub-clause 4.4 of IEC Publication 694);

*h)* rated breaking currents as defined in Clause 3 and Clause 4, if applicable;

*i)* if applicable, rated short-circuit making current as defined in Sub-clause 3.124 and Sub-clause 4.110;

*j)* rated duration of short-circuit current (Sub-clause 4.7 of IEC Publication 694).

2) *Type tests*

Certificate or report on request, including the special tests requested by the enquirer.

3) *Constructional features*

*a)* for oil switches: mass of complete switch without oil; mass of oil, recommendations regarding oil quality; number of tanks;

b) for air-blast switches: mass of complete switch; air pressure and limits of air pressure between which the switch will operate correctly; the capacity of the local air receiver; quantity of free air for one opening operation and for one closing operation; recommendations regarding air quality;

c) for other gas switches: mass of complete switch; gas pressure and limits of gas pressure within which the switch will operate correctly; the total volume of the gas per pole at a pressure of 0.1 MPa (1 bar); if applicable, tightness characteristics, recommendations regarding gas quality;

d) number of breaks in series per pole;

e) minimum clearances in air;
  - between poles,
  - to earth.

4) *Operating mechanism of switch and associated equipment*

a) type of operating mechanism;

b) rated supply voltage of closing and opening devices (Sub-clause 4.8 of IEC Publication 694);

c) rated supply frequency (Sub-clause 4.9 of IEC Publication 694);

d) rated pressure of compressed gas supply for operation (Sub-clause 4.10 of IEC Publication 694);

e) current required at rated supply voltage to close and open the switch;

f) quantity of free air required to close and open the switch at rated supply pressure;

g) rated supply voltage of shunt opening release;

h) current required at rated supply voltage for shunt opening release;

i) number and type of spare auxiliary switch contacts;

j) current required at rated supply voltage by other auxiliaries.

5) *Overall dimensions and other information*

The manufacturer should give the necessary information regarding overall dimensions of the switch and details necessary for the design of the foundation. General information regarding maintenance should also be given.

## 10. Rules for transport, storage, erection and maintenance

Clause 10 of IEC Publication 694 is applicable.

### TABLE I

### *Rated line and cable charging breaking currents for a general purpose switch*

| Rated voltage $U$ (kV) | Rated cable-charging breaking current $I_{4a}$ (A) | Rated line-charging breaking current $I_{4b}$ (A) |
|---|---|---|
| 52 | 25 | 2 |
| 72.5 | 25 | 3 |
| 100 | 31.5 | 5 |
| 123 | 31.5 | 8 |
| 145 | 31.5 | 10 |
| 170 | 40 | 12.5 |
| 245 | 40 | 25 |
| 300 | 50 | 31.5 |
| 362 | 50 | 50 |
| 420 | 63 | 63 |
| 525 | — | 80 |
| 765 | — | 125 |

*Notes 1.* – Higher values selected from the R10 series may be stated by the manufacturer.

*2.* – Refer to I E C Publication 56 for suggested rated line and cable charging breaking currents for a special purpose switch.

## TABLE II

### *Nameplate information*

| (1) | Abbreviation (2) | Unit (3) | Switch (4) | Operating device (5) | Condition: marking required only if (6) |
|---|---|---|---|---|---|
| Manufacturer | | | x | x | |
| Designation of type | | | x | x | |
| Serial number | | | (x) | (x) | |
| Rated voltage | $U$ | kV | x | | |
| Rated lightning impulse withstand voltage | $U_w$ | kV | x | | |
| Rated switching impulse withstand voltage | $U_s$ | kV | y | | Rated voltage 300 kV and above |
| Rated frequency | | Hz | x | | |
| Rated normal current | $I_n$ | A | x | | |
| Rated short-time current | $I_{th}$ | kA | x | | |
| Rated duration of short circuit | $t$ | s | y | | Different from 1 s |
| Rated short-circuit making current | $I_{ma}$ | kA | x | | |
| Number of operations for mainly active load breaking | $n$ | | y | | Different from 10 |
| Rated mainly active load breaking current | $I_1$ | A | (x) | | |
| Rated transmission line closed loop breaking current | $I_{2a}$ | A | (x) | | |
| Rated parallel transformer breaking current | $I_{2b}$ | A | (x) | | |
| Rated cable-charging breaking current | $I_{4a}$ | A | (x) | | |
| Rated line-charging breaking current | $I_{4b}$ | A | (x) | | |
| Rated busbar charging breaking current | $I_{4c}$ | A | (x) | | |
| Rated single capacitor bank breaking current | $I_{4d}$ | A | (x) | | |
| Rated back-to-back capacitor bank breaking current | $I_{4e}$ | A | (x) | | |
| Rated no-load transformer breaking current | $I_{5a}$ | A | (x) | | |
| Rated shunt reactor breaking current | $I_{5b}$ | A | (x) | | |
| Rated earth-fault breaking current | $I_{7a}$ | A | (x) | | |
| Rated cable and line charging breaking current under earth-fault conditions | $I_{7b}$ | A | (x) | | |
| Rated back-to-back capacitor bank inrush making current | $I_{in}$ | A | (x) | | |
| Rated pressure for operating device | $P_{op}$ | MPa or bar | | (x) | |
| Rated gas pressure for switch | $P_{sw}$ | MPa or bar | (x) | | |
| Rated auxiliary voltage | $U_a$ | V | | x | |
| Mass (including liquid) | $m$ | kg | y | y | More than 300 kg |
| Temperature class | | | y | y | Different from:<br>−5 °C indoor or<br>−25 °C outdoor |

x The marking of these values is mandatory; blanks for these values on the nameplate indicate the value zero.
(x) The marking of these values is optional.
y The marking of these values is subject to the condition in Column (6).

*Notes:*

*1.* Abbreviations in Column (2) may be used instead of terms in Column (1). When terms of Column (1) are used, the word "rated" need not appear.

*2.* It is permissible to combine abbreviations where values are identical, for example: $I_n$ $I_1$ $I_{2a}$ 400 A.

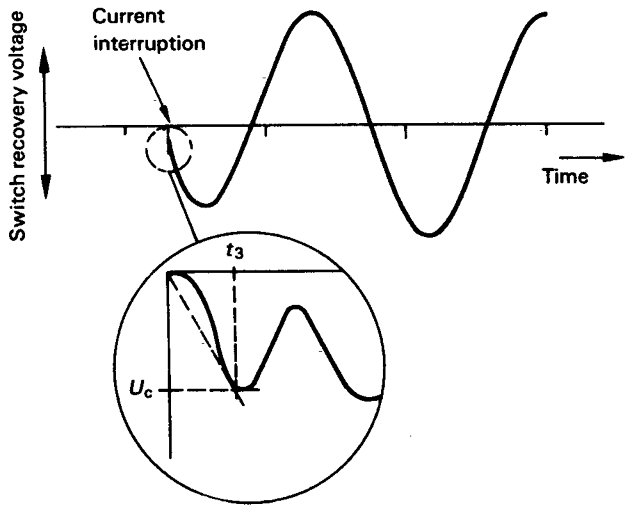
## TABLE III

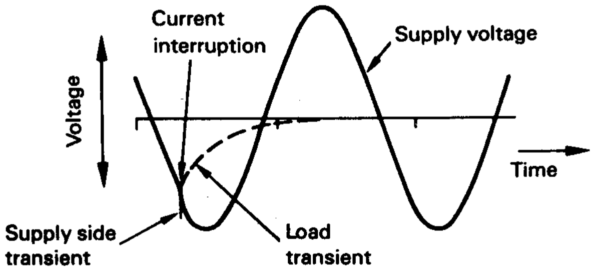
### *Supply circuit TRV parameters for mainly active load current breaking tests*

| Rated voltage $U$ (kV) | Supply component | |
|---|---|---|
| | Peak voltage $U_c$ (kV) | Time coordinate $t_3$ (μs) |
| 52 | 11 | 23 |
| 72.5 | 15 | 28 |
| 100 | 21 | 34 |
| 123 | 26 | 40 |
| 145 | 30 | 45 |
| 170 | 36 | 51 |
| 245 | 34 | 66 |
| 300 | 42 | 73 |
| 362 | 50 | 82 |
| 420 | 60 | 88 |
| 525 | 73 | 98 |
| 765 | 105 | 114 |

*Notes:*

*1.* – The transient is of the (l-cos) form and the values are for the first pole to clear. The switch supply and load transients are illustrated below.





*2.* – The series supply impedance is 15% of the total impedance with a power factor of 0.2 or less. The load consists of parallel resistance and reactance. The TRV from the load is an exponentially decaying voltage whose peak is determined by the power factor of the load. Thus, the load side TRV is completely determined by the load circuit and need not be specified.

*3.* – The series supply impedance is a combination of local transformer impedance (10% assumed) and remote supply impedance (5% assumed). The transformer TRV frequency is much greater than the remote supply TRV frequency, therefore the supply circuit component of the TRV is derived only from the transformer contribution. The first-pole-to-clear factor $K_\varphi$ is 1.5 for rated voltages below 245 kV assuming isolated neutral transformers and 1.0 for rated voltages 245 kV and above, assuming earthed neutral transformers. The amplitude factor is assumed to be 1.7 in accordance with IEC Publication 56 for short-circuit test duty No. 1.

$$U_c = U \sqrt{\frac{2}{3}} \times K_\varphi \times 1.7 \times 0.10$$

## TABLE IV A

### *TRV parameters for transmission line closed loop current breaking tests*

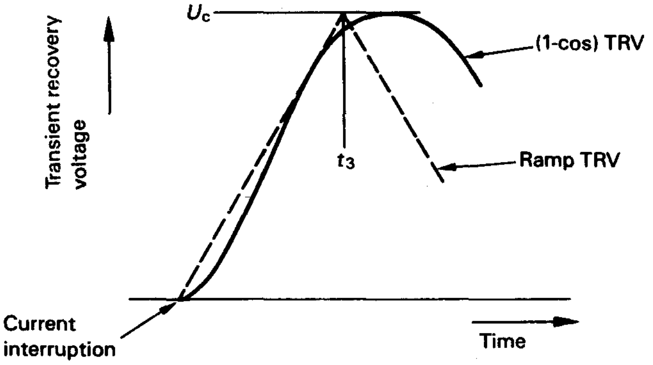
| Rated voltage $U$ (kV) | Peak voltage $U_c$ (kV) | RRRV[1] $U_c/t_3$ (kV/μs per kA) 60 Hz | RRRV[1] $U_c/t_3$ (kV/μs per kA) 50 Hz |
|---|---|---|---|
| 52 | 14 | 0.227 | 0.189 |
| 72.5 | 19 | 0.227 | 0.189 |
| 100 | 26 | 0.227 | 0.189 |
| 123 | 32 | 0.227 | 0.189 |
| 145 | 38 | 0.227 | 0.189 |
| 170 | 44 | 0.227 | 0.189 |
| 245 | 64 | 0.227 | 0.189 |
| 300 | 59 | 0.174 | 0.145 |
| 362 | 71 | 0.174 | 0.145 |
| 420 | 82 | 0.174 | 0.145 |
| 525 | 105 | 0.174 | 0.145 |
| 765 | 150 | 0.174 | 0.145 |

[1] The time coordinate can be calculated from RRRV per kA for a given peak voltage $U_c$ and test current in kA.

$$t_3 = \frac{U_c}{(\text{RRRV}) \times (\text{kA})}$$

*Notes:*

*1.* – The transient is of the form of a linear ramp to crest voltage. For convenience in testing, a transient of the (1-cos) form may be used. A typical transient is illustrated below.



*2.* – Steady-state, phase-to-phase, open circuit test voltage is to be 20% of rated voltage below 300 kV and 15% of rated voltage of 300 kV and above. $U_c$ is based on an earthed neutral system having a first-pole-to-clear factor $K_\varphi$ of 1.0 and an amplitude factor equal to 1.6 in accordance with IEC Publication 56 regarding amplitude factors associated with short-line faults.

$$U_c = U \times (0.20 \text{ or } 0.15) \sqrt{\frac{2}{3}} \times 1.0 \times 1.6$$

*3.* – The RRRV is based on d*i*/d*t* times the equivalent surge impedance $Z_{eq}$. The equivalent surge impedance was calculated for the first-pole-to-open since the switch current is the highest in this case.

$$Z_{eq} = \frac{3\left(\frac{Z_1}{2}\right) Z_0}{\left(\frac{Z_1}{2}\right) + Z_0}$$

where $Z_1$ = positive sequence surge impedance and $Z_0$ = zero sequence surge impedance

$Z_{eq}$ is 425 Ω for 245 kV and below and 325 Ω above 245 kV. $Z_{eq}$ is not the same as that typically used for short line faults. $Z_{eq}$ is for the first pole to open rather than the last pole to open used in short line faults. The surge impedance changes above 245 kV because of the use of bundled conductors. Also note that the conductors do not clash together during closed loop switching.

## TABLE IVB

### *TRV parameters for parallel transformer current breaking tests*

| Rated voltage $U$ (kV) | Peak voltage $U_c$ (kV) | Time coordinate factor K[1] | |
|---|---|---|---|
| | | 60 Hz | 50 Hz |
| 52 | 8.1 | 11 | 12 |
| 72.5 | 11.5 | 13 | 14 |
| 100 | 16 | 16 | 17 |
| 123 | 19 | 17 | 19 |
| 145 | 23 | 22 | 24 |
| 170 | 27 | 24 | 27 |
| 245 | 26 | 28 | 31 |
| 300 | 31 | 32 | 35 |
| 362 | 38 | 44 | 48 |
| 420 | 44 | 47 | 51 |
| 525 | 55 | 61 | 67 |
| 765 | 80 | 61 | 67 |

[1] The time coordinate is calculated as $t_3 = \dfrac{K}{\sqrt{I}}$

where $t_3$ is in µs and I is the test current in kA.

*Notes:*

*1.* – The transient is of the (1-cos) form and the values are for the first pole to clear.

*2.* – The first-pole-to-clear factor $K_\varphi$ is 1.0 for rated voltages of 245 kV and above, assuming earthed neutral systems, and 1.5 for rated voltages below 245 kV, assuming isolated neutral systems. Amplitude factor is assumed to be 1.7 in accordance with IEC Publication 56 for short-circuit test duty No. 1. It is assumed that two transformers are in parallel with one transformer being switched. The TRV is mainly from the transformer being switched. This implies that the transient is based only on half of the steady state recovery voltage.

$$U_c = U\sqrt{\frac{2}{3}} \times K_\varphi \times 1.7 \times \frac{0.15}{2}$$

*3.* – The K factor was derived from transient recovery voltage frequencies obtained by low-voltage current injection of transformers. The frequency is typical of transformers having a current rating close to the test current.

## TABLE V

## *TRV parameters for shunt reactor current breaking tests*

| Rated voltage $U$ (kV) | Peak voltage $U_c$ (kV) | Time coordinate factor K[1] | |
|---|---|---|---|
| | | 60 Hz | 50 Hz |
| 52 | 120 | 40 | 43 |
| 72.5 | 170 | 47 | 51 |
| 100 | 230 | 55 | 60 |
| 123 | 290 | 61 | 67 |
| 145 | 340 | 66 | 73 |
| 170 | 400 | 72 | 79 |
| 245 | 380 | 86 | 94 |
| 300 | 470 | 95 | 105 |
| 362 | 560 | 105 | 115 |
| 420 | 650 | 115 | 125 |
| 525 | 810 | 125 | 140 |
| 765 | 1200 | 150 | 170 |

[1] The time coordinate is calculated as $t_3 = \frac{K}{\sqrt{I}}$

where $t_3$ is in µs and I is the test current in kA.

*Notes:*

*1.* – The transient is of the (1-cos) form and the values are for the first pole to clear.

*2.* – The first-pole-to-clear factor $K_\varphi$ is 1.0 for rated voltages of 245 kV and above assuming earthed neutral reactors and 1.5 for rated voltages below 245 kV assuming isolated neutral reactors. The amplitude factor is assumed to be 1.9.

$$U_c = U\sqrt{\frac{2}{3}} \times K_\varphi \times 1.9$$

*3.* – The K factor was derived from low-voltage, current injection of high voltage shunt reactors.

### TABLE VI

### *Test-duties for three phase tests on three-pole switches*

| Test-duty | | Rated voltage | Test voltage [1] (+10%, −0%) | Test current (+10%, −0%) | Number of cycles or operations |
|---|---|---|---|---|---|
| No. | Type | | | | |
| 1* | 100% mainly active load current | All | $U$ | $I_1$ | 10 |
| 2a* | Closed loop-transmission circuit current | $<300$ kV | $0.20\,U$ | $I_{2a}$ | 10 |
| | | $\geqslant 300$ kV | $0.15\,U$ | | |
| 2b* | Closed loop-parallel transformer circuit current | All | $0.15\,U$ | $I_{2b}$ | 10 |
| 3* | 5% mainly active load current | All | $U$ | $0.05\,I_1$ | 20 |
| 4a* | Cable charging current | All | $U$ | $I_{4a}$ | 10 |
| | | | | $0.2-0.4\,I_{4a}$ | 10 |
| 4b* | Line charging current | All | $U$ | $I_{4b}$ | 10 |
| | | | | $0.2-0.4\,I_{4b}$ | 10 |
| 4c | Bus-bar charging current | All | ** | ** | ** |
| 4d | Single capacitor bank current | All | $U$ | $I_{4d}$ | 10 |
| | | | | $0.2-0.4\,I_{4d}$ | 10 |
| 4e | Back-to-back capacitor bank current | All | $U$ | $I_{4e}$ | 10 |
| | | | | $0.2-0.4\,I_{4e}$ | 10 |
| 5a | No-load transformer current | All | ** | ** | ** |
| 5b | Shunt reactor current | All | $U$ | $I_{5b}$ | 10 |
| | | | | $0.2-0.4\,I_{5b}$[2] | 10 |
| 6* | Short-circuit making current | All | $U$ | $I_{ma}$ | 2 making operations |
| 7a | Earth fault current | $<245$ kV | $U$ | $I_{7a}$ | 10 |
| 7b | Cable and line charging current under earth faults | $<245$ kV | $U$ | $I_{7b}$ | 10 |

* These test-duties required for a general purpose switch.

** By agreement between manufacturer and user.

[1] TRV parameters are as shown in appropriate table for the first pole to clear.

[2] If a minimum breaking current is specified, then the test shall be performed at the minimum rating rather than at $0.2-0.4\,I_{5b}$.

## TABLE VII A

*Test-duties for single phase tests on three-pole switches with 0.5 cycle or less non-simultaneity*

| Test-duty | | Rated voltage | Test voltage [1] (+10%, −0%) | Test current (+10%, −0%) | Number of cycles or operations |
|---|---|---|---|---|---|
| No. | Type | | | | |
| 1* | 100% mainly active load current | <245 kV | 1.5 $U/\sqrt{3}$ [3] | $I_1$ | 10 |
| | | ≥245 kV | $U/\sqrt{3}$ | $I_1$ | 10 |
| 2a* | Closed loop-transmission circuit current | <300 kV | 0.20 $U/\sqrt{3}$ | $I_{2a}$ | 10 |
| | | ≥300 kV | 0.15 $U/\sqrt{3}$ | | |
| 2b* | Closed loop-parallel transformer circuit current | <245 kV | 1.5 (0.15) $U/\sqrt{3}$ | $I_{2b}$ | 10 |
| | | ≥245 kV | 0.15 $U/\sqrt{3}$ | $I_{2b}$ | 10 |
| 3* | 5% mainly active load current | <245 kV | 1.5 $U/\sqrt{3}$ [3] | 0.05 $I_1$ | 20 |
| | | ≥245 kV | $U/\sqrt{3}$ | 0.05 $I_1$ | 20 |
| 4a* [2] | Cable charging current | All | $U/\sqrt{3}$ | $I_{4a}$ | 12 [6] |
| | | | | 0.2−0.4 $I_{4a}$ | 12 [6] |
| 4b* [2] | Line charging current | All | 1.2 $U/\sqrt{3}$ [3] | $I_{4b}$ | 12 [6] |
| | | | | 0.2−0.4 $I_{4b}$ | 12 [6] |
| 4c | Bus-bar charging current | All | ** | ** | ** |
| 4d [2] | Single capacitor bank current | All | [3], [4] | $I_{4d}$ | 12 [6] |
| | | | | 0.2−0.4 $I_{4d}$ | 12 [6] |
| 4e [2] | Back-to-back capacitor bank current | All | [3], [4] | $I_{4e}$ | 12 [6], [7] |
| | | | | 0.2−0.4 $I_{4e}$ | 12 [6] |
| 5a | No-load transformer current | All | ** | ** | ** |
| 5b | Shunt reactor current | <245 kV | 1.5 $U/\sqrt{3}$ [3] | $I_{5b}$ | 12 [6] |
| | | | | 0.2−0.4 $I_{5b}$ [8] | 12 [6] |
| | | ≥245 kV | $U/\sqrt{3}$ | $I_{5b}$ | 12 [6] |
| | | | | 0.2−0.4 $I_{5b}$ [8] | 12 [6] |
| 6* [5] | Short-circuit making current | All | $U/\sqrt{3}$ | $I_{ma}$ | 2 making operations |
| 7a | Earth fault current | <245 kV | $U/\sqrt{3}$ | $I_{7a}$ | 10 |
| 7b | Cable and line charging current under earth faults | <245 kV | $U$ | $I_{7b}$ | 10 |

* These test-duties required for a general purpose switch.

** By agreement between manufacturer and user.

[1] TRV values are as specified in appropriate tables.

[2] These tests are allowed only for switches with 0.25 cycle or less non-simultaneity. Otherwise, tests shall be as specified in Table VII B.

[3] Test voltage can be reduced to $U/\sqrt{3}$ for making operations.

[4] It is recommended that only earthed neutral systems and earthed neutral capacitors be considered for rated voltages of 245 kV and above. For lower voltage systems, isolated neutral supply and/or isolated neutral capacitor banks are to be expected. The test circuit shall be representative of intended application. The test voltage shall equal the product of $U/\sqrt{3}$ and one of the following factors:

a) 1.0 for tests corresponding to earthed neutral systems without significant mutual influence of adjacent phases of the capacitive circuit; for example, capacitor banks with earthed neutrals,

b) 1.4 for tests corresponding to breaking in systems other than earthed neutral systems or breaking currents of capacitor banks with isolated neutrals.

[5] Only allowed for switches with less than 0.5 cycle-simultaneity during contact make. Otherwise, the test shall be as specified in Table VII B.

[6] Point-on-wave tripping to control contact parting at 30 electrical degree increment. If this is not possible, 30 random operations shall be used.

[7] At least three of the making operations shall take place within 15 electrical degrees of voltage peak.

[8] If a minimum breaking current is specified, then the test shall be performed at the minimum rating rather than at 0.2−0.4 $I_{5b}$.

## TABLE VIIB

### *Test-duties for single phase tests on three-pole switches with more than 0.5 cycle non-simultaneity and switches operated pole after pole*[1]

| Test-duty | | Rated voltage | Test voltage[2] (+10%, −0%) | Test current (+10%, −0%) | Number of cycles or operations |
|---|---|---|---|---|---|
| No. | Type | | | | |
| 1* | 100% mainly active load current | <245 kV[3] | 1.5 $U/\sqrt{3}$ | $I_1$ | 5 |
| | | | $U$[4] | 0.87 $I_1$ | 5 |
| | | ≥245 kV | $U/\sqrt{3}$ | $I_1$ | 10 |
| 2a* | Closed loop-transmission circuit current | <300 kV | 0.20 $U/\sqrt{3}$ | $I_{2a}$ | 10 |
| | | ≥300 kV | 0.15 $U/\sqrt{3}$ | | |
| 2b* | Closed loop-parallel transformer circuit current | <245 kV | 1.5 (0.15) $U/\sqrt{3}$ | $I_{2b}$ | 10 |
| | | ≥245 kV | 0.15 $U/\sqrt{3}$ | $I_{2b}$ | 10 |
| 3* | 5% mainly active load current | <245 kV | $U$[4] | 0.05 $I_1$ | 20 |
| | | ≥245 kV | $U/\sqrt{3}$ | 0.05 $I_1$ | 20 |
| 4a* | Cable charging current | All | $U/\sqrt{3}$ | $I_{4a}$ | 12[8] |
| | | | | 0.2–0.4 $I_{4a}$ | 12[8] |
| 4b* | Line charging current | All | [5] | $I_{4b}$ | 12[8] |
| | | | | 0.2–0.4 $I_{4b}$ | 12[8] |
| 4c | Bus-bar charging current | All | ** | ** | ** |
| 4d | Single capacitor bank current | All | [6] | $I_{4d}$ | 12[8] |
| | | | | 0.2–0.4 $I_{4d}$ | 12[8] |
| 4e | Back-to-back capacitor bank current | All | [6] | $I_{4e}$ | 12[8],[9] |
| | | | | 0.2–0.4 $I_{4e}$ | 12[8] |
| 5a | No-load transformer current | All | ** | ** | ** |
| 5b | Shunt reactor current | <245 kV[3] | 1.5 $U/\sqrt{3}$ | $I_{5b}$ | 12[8] |
| | | | $U$[4] | 0.87 $I_{5b}$ | 12[8] |
| | | | | 0.2–0.4 $I_{5b}$[10] | 12[8] |
| | | ≥245 kV | $U/\sqrt{3}$ | $I_{5b}$ | 12[8] |
| | | | | 0.2–0.4 $I_{5b}$[10] | 12[8] |
| 6* | Short-circuit making current | All[7] | $U$ | 0.87 $I_{ma}$ | 1 making operation |
| | | | 1.5 $U/\sqrt{3}$ | $I_{ma}$ | 1 making operation |
| 7a | Earth fault current | <245 kV | $U/\sqrt{3}$ | $I_{7a}$ | 10 |
| 7b | Cable and line charging current under earth faults | <245 kV | $U$ | $I_{7b}$ | 10 |

* These test-duties required for a general purpose switch.

** By agreement between manufacturer and user.

[1] Pole non-simultaneity is the maximum time between the instant contact separation of the first pole and last pole.

[2] TRV values are as specified in appropriate tables.

[3] Two test series are necessary for complete evaluation. However, one test series at $U$ at rated current is allowed as long as a total of ten operations is performed for test-duty 1 and 12 operations are performed for test-duty 5b. The TRV parameters shall be as specified in Item [4].

[4] The peak TRV values shall be 1.15 times the values shown in the appropriate tables.

[5] For switches operated pole after pole, use 1.2 $U/\sqrt{3}$. For all others, use 1.4 $U/\sqrt{3}$.

[6] It is recommended that only earthed neutral systems and earthed neutral capacitors be considered for rated voltages of 245 kV and above. For lower voltage systrems, isolated neutral supplies and/or isolated neutral capacitor banks are to be expected. The

manufacturer shall select the test circuit to be representative of intended application. The test voltage shall equal the product of $U\sqrt{3}$ and one of the following factors:

a) 1.0 for tests corresponding to earthed neutral systems without significant mutual influence of adjacent phases of the capacitive circuit; for example, capacitor banks with earthed neutrals;

b) 1.75 for switches operated pole after pole for tests corresponding to breaking in systems other than earthed neutral systems, or breaking of currents of capacitor banks with isolated neutrals.

c) 2.0 for three-pole switches for tests corresponding to breaking in systems other than earthed neutral systems or breaking of currents of capacitor banks with isolated neutrals. Lower values may be used by agreement between manufacturer and user depending upon non-simultaneity of the particular switch.

[7] For switches operated pole after pole, two tests are required but the test voltage at $1.0 I_{ma}$ shall be $U/\sqrt{3}$.

[8] Point-on-wave tripping to control contact parting at 30 electrical degree increments. If this is not possible, 30 random operations shall be used.

[9] At least three of the making operations shall take place within 15 electrical degrees of voltage peak.

[10] If a minimum breaking current is specified, then the test shall be performed at the minimum rating rather than at $0.2-0.4\ I_{5b}$.

## TABLE VIII

*Recovery voltage requirements for single-phase capacitive current breaking tests*

| Recovery voltage [1], [2] | | Time coordinates [1] | | |
|---|---|---|---|---|
| $U_c$ | $U_a$ [4] | $t_a$ [4] | $t_2$ ms | |
| | | | 50 Hz | 60 Hz |
| ≥1.95 | ≤0.07 | ≥$t_1$ or $t_3$ [3] | ≤8.7 | ≤7.3 |

[1] Values are shown in Figure 7.

[2] Values are per-unit with respect to the peak value of the test voltage.

[3] $t_1$ or $t_3$ in Table II A, B, C, D and E of IEC Publication 56.

[4] The initial part of the prospective TRV shall be below a line defined by the origin and by $U_a$ and $t_a$ as shown in Figure 7.

## TABLE IX

## *Suggested maximum permissible switching overvoltages when switching capacitive and inductive currents*

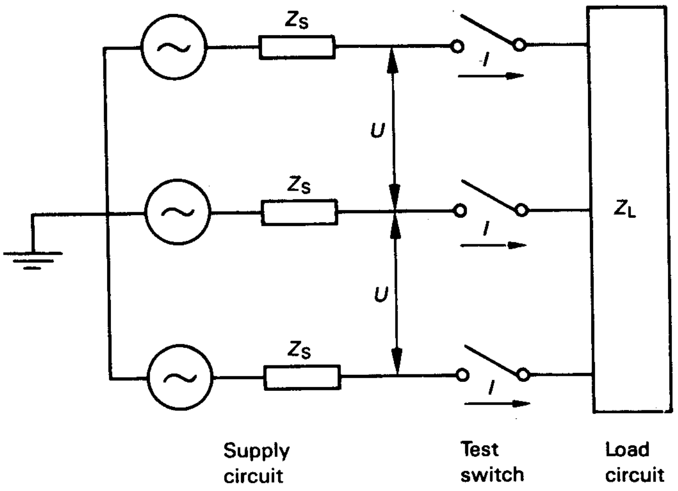
| Rated voltage $U$ (kV r.m.s.) | Rated lightning impulse withstand voltage (kV peak) | Maximum permissible switching overvoltages to earth | | | |
|---|---|---|---|---|---|
| | | A | | B | |
| | | (kV peak) | P. U. of column (1) times $\frac{\sqrt{2}}{\sqrt{3}}$ | (kV peak) | P. U. of column (1) times $\frac{\sqrt{2}}{\sqrt{3}}$ |
| (1) | (2) | (3) | (4) | (5) | (6) |
| 52 | 250 | 149 | 3.5 | 106 | 2.5 |
| 72.5 | 325 | 207 | 3.5 | 148 | 2.5 |
| 100 | 380 | 246 | 3 | 204 | 2.5 |
| | 450 | 286 | 3.5 | 204 | 2.5 |
| 123 | 450 | 302 | 3 | 251 | 2.5 |
| | 550 | 352 | 3.5 | 251 | 2.5 |
| 145 | 550 | 356 | 3 | 297 | 2.5 |
| | 650 | 415 | 3.5 | 297 | 2.5 |
| 170 | 650 | 417 | 3 | 348 | 2.5 |
| | 750 | 487 | 3.5 | 348 | 2.5 |
| 245 | 850 | 540 | 2.7 | 400 | 2 |
| | 950 | 600 | 3 | 400 | 2 |
| | 1 050 | 600 | 3 | 400 | 2 |
| 300 | 950 | 637 | 2.6 | 490 | 2 |
| | 1 050 | 735 | 3 | 490 | 2 |
| 362 | 1 050 | 710 | 2.4 | 592 | 2 |
| | 1 175 | 800 | 2.7 | 592 | 2 |
| 420 | 1 300 | 790 | 2.3 | 688 | 2 |
| | 1 425 | 895 | 2.6 | 688 | 2 |
| 525 | 1 425 | 900 | 2.1 | 858 | 2 |
| | 1 550 | 985 | 2.3 | 858 | 2 |
| 765 | 1 800 | 1 125 | 1.8 | 1 125 | 1.8 |
| | 2 100 | 1 250 | 2 | 1 250 | 2 |

*Notes 1.* – Limitation of the maximum switching overvoltage to these values cannot guarantee that phase-to-phase flashovers will not occur.

*2.* – The values of columns A apply to general purpose switches intended for switching capacitive and inductive circuits most generally used in power systems.

The values of columns B apply to special purpose switches intended for switching capacitive and inductive circuits in power systems where there are special insulation co-ordination problems such as, for instance, limitation of energy absorption by surge diverters, spark-over of spark-gaps, etc.

*3.* – At 245 kV and above, only earthed neutral systems and capacitor banks or shunt reactors with earthed neutrals are considered for the application of the values of columns B.



Test-duty 1:
$I = I_1$

Test-duty 3:
$I = 0.05\, I_1$

Supply circuit:
Power factor $\leq 0.2$
$Z_T = Z_S + Z_L$
$|Z_S| = (0.15 \pm 0.03)\,|Z_T|$
TRV parameters: Table III

Load circuit:
Power factor = 0.65 to 0.75

FIG. 1a. – General circuit.

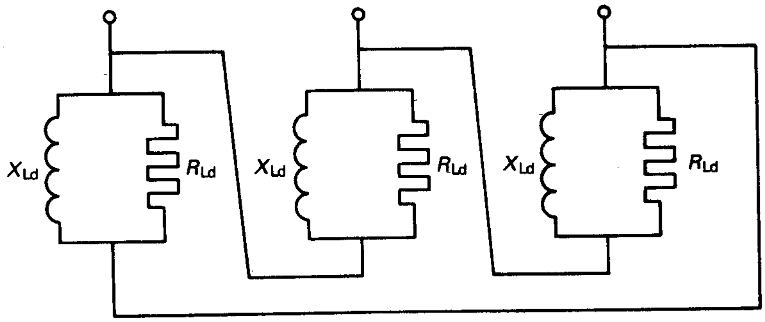


FIG. 1b. – Delta load connection.

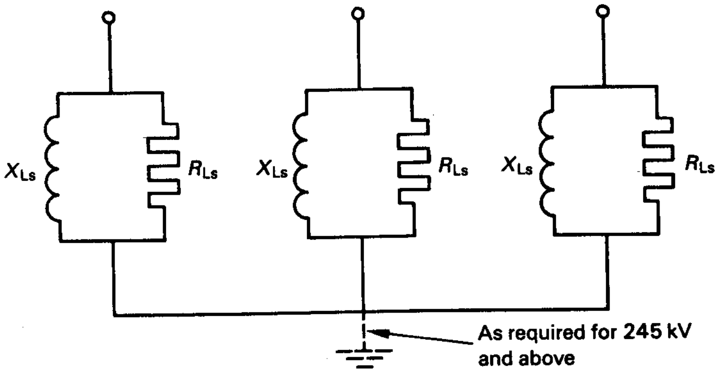
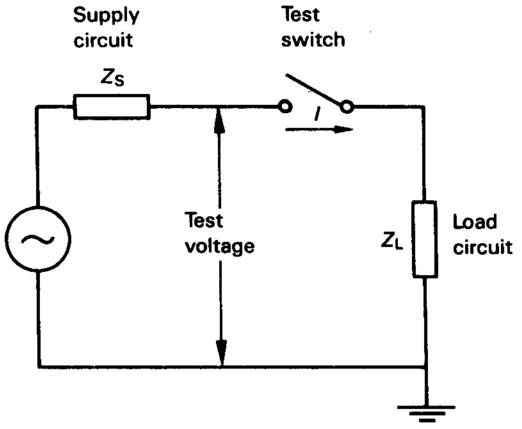


FIG. 1c. – Star load connection.

FIG. 1. – Three-phase test circuit for mainly active load current switching, for test-duties 1 and 3.

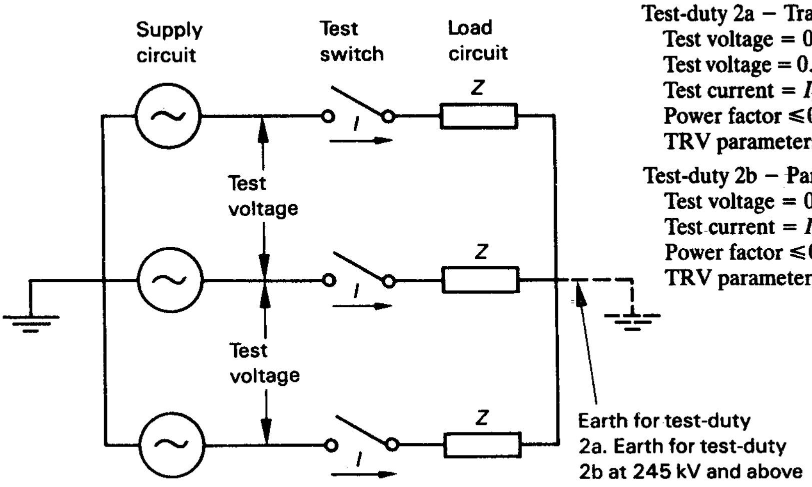


Test voltage and current defined in Table VII A and VII B

Supply circuit:
Power factor $\leq 0.2$
$Z_T = Z_S + Z_L$
$|Z_S| = (0.15 \pm 0.03)|Z_T|$
TRV parameters: Tables III, VII A and VII B

Load circuit:
Power factor = 0.65 to 0.75

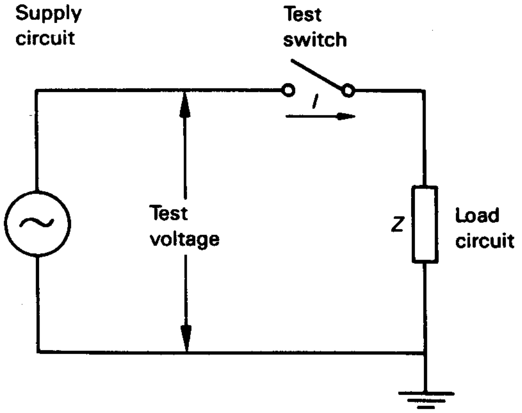
FIG. 2. – Single-phase test circuit for mainly active load current switching for test-duties 1 and 3.



Test-duty 2a – Transmission circuit:
Test voltage = 0.20 $U$ for rated voltages below 300 kV
Test voltage = 0.15 $U$ for rated voltages 300 kV and above
Test current = $I_{2a}$
Power factor $\leq 0.3$
TRV parameters: Table IV A

Test-duty 2b – Parallel-transformer circuit:
Test voltage = 0.15 $U$
Test current = $I_{2b}$
Power factor $\leq 0.2$
TRV parameters: Table IV B

FIG. 3. – Three-phase test circuit for transmission line closed loop and parallel-transformer current switching test for test-duties 2a and 2b.



Test-duty 2a – Transmission line closed loop circuit:
Test voltage, current and TRV parameters defined in Tables IV A, VII A and VII B
Power factor $\leq 0.3$

Test-duty 2b – Parallel-transformer circuit:
Test voltage, current and TRV parameters defined in Tables IV B, VII A and VII B
Power factor $\leq 0.2$

FIG. 4. – Single-phase test circuit for transmission line closed loop and parallel-transformer current switching test, for test-duties 2a and 2b.

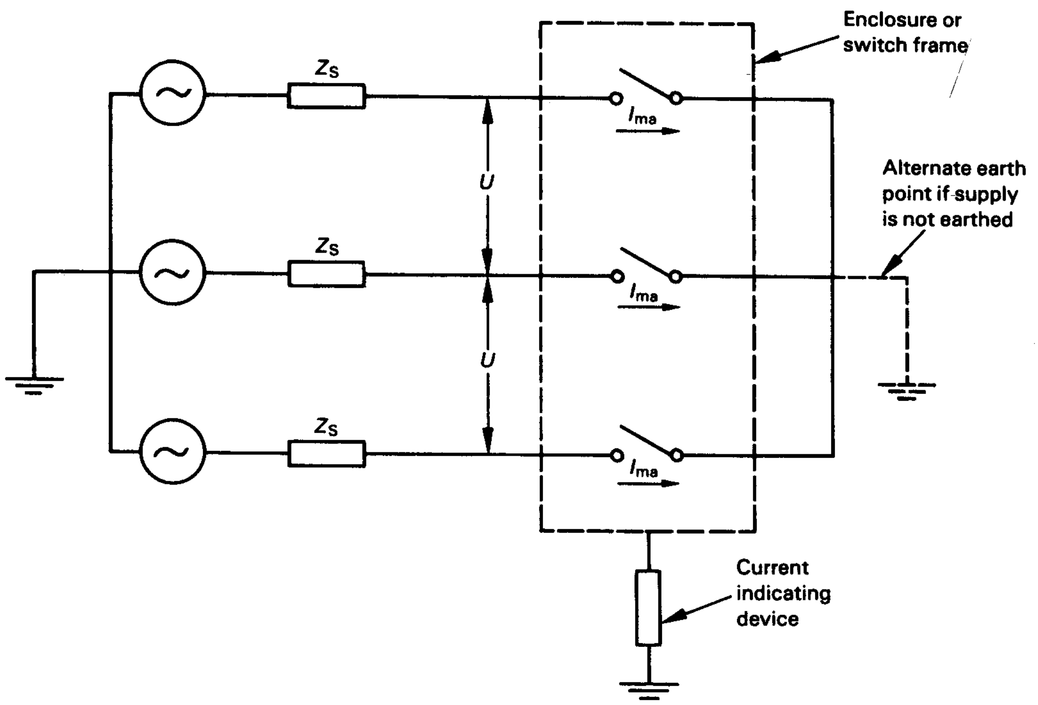

Enclosure or switch frame
$Z_S$
$Z_S$
$Z_S$
$U$
$U$
$I_{ma}$
$I_{ma}$
$I_{ma}$
Alternate earth point if supply is not earthed
Current indicating device

FIG. 5. – Three-phase test circuit for short circuit making current test for test-duty 6.

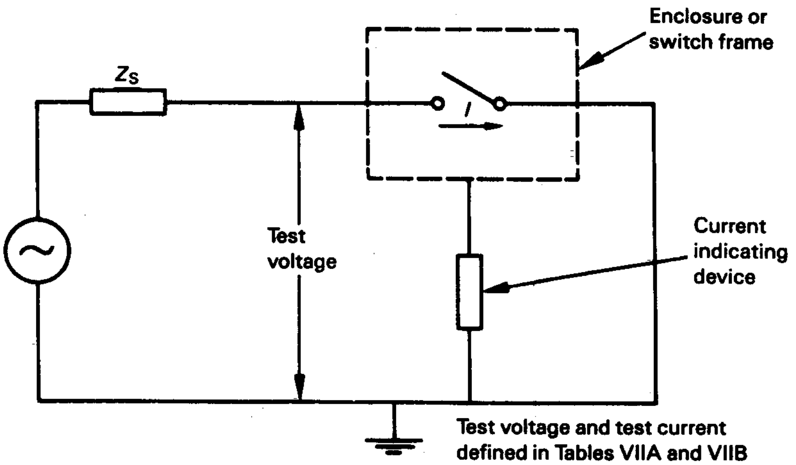

Enclosure or switch frame
$Z_S$
$I$
Test voltage
Current indicating device
Test voltage and test current defined in Tables VIIA and VIIB

FIG. 6. – Single-phase test circuit for short circuit making current test, for test-duty 6.

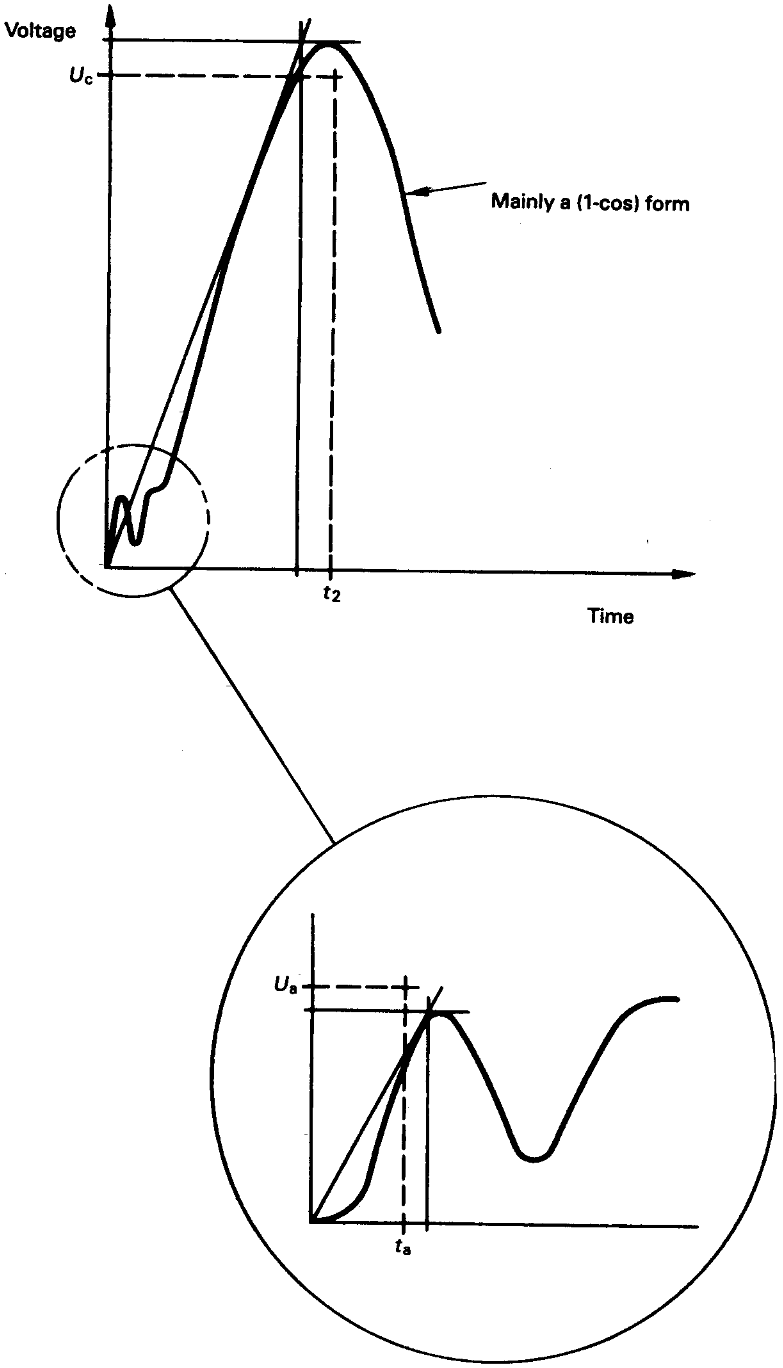


FIG. 7. – Recovery voltage for capacitive current breaking tests.

# AMENDMENT NO. 1

Page 21

6.101.15 *Condition of switch after breaking tests*

*Replace the existing third and fourth paragraphs by the following new text:*

Visual inspection and no-load operation of the switch after tests are usually sufficient for verification of the above requirements. In case of doubt, it may be necessary to perform the appropriate tests for confirmation.

If the insulation properties across open contacts of a switch or the isolating properties of a switch-disconnector are doubted, a condition checking test according to 6.1.11 of IEC 694 is deemed to verify the properties. For switches with sealed-for-life interrupters, the condition checking test is mandatory.

Page 22

6.101.16 *Condition of switch during and after short-circuit making tests*

*Replace the existing item c) by the following new text:*

c) dielectric requirements: the insulating properties across the open switch and to earth shall not be reduced below what corresponds to normal wear and ageing by deterioration of insulating parts.

If the insulation properties across open contacts of a switch or the isolating properties of a switch-disconnector are doubted, a condition checking test according to 6.1.11 of IEC 694 is deemed sufficient to verify the properties. For switches with sealed-for-life interrupters, the condition checking test is mandatory.

# AMENDMENT NO. 2

Page 24

**6.102.3 Tests for limited-purpose and special-purpose switches**

*Add, after the existing paragraph, the following new paragraph:*

In the case of frequently operated switches, extended mechanical endurance tests may be carried out according to subclause 6.102.4 of IEC 60265-1.

( *Continued from second cover* )

| *International Standard* | *Corresponding Indian Standard* | *Degree of Equivalence* |
|---|---|---|
| IEC 59 ( 1938 ) IEC standard current ratings | IS 11955 : 1987 Preferred current ratings | Equivalent |
| IEC 71-1 (1976) Insulation co-ordination, Part 1: Terms, definitions, principles and rules | IS 2165 ( Part 1 ) : 1977 Insulation co-ordination : Part 1 Phase to earth insulation coordination | do |
| IEC 129 ( 1984 ) Alternating current disconnectors ( isolators ) and earthing switches | IS 9921 ( Part 1 ) : 1981 Alternating current disconnectors ( isolators ) and earthing switches for voltages above 1 000 V : Part 1 General and definitions | do |
| IEC 270 ( 1981 ) Partial discharge measurements | IS 6209 : 1982 Methods for partial discharge measurement ( *first revision* ) | do |
| IEC 694 ( 1980 ) Common clauses for high-voltage switchgear and controlgear standards | IS 12729 : 1988 General requirements for switchgear and controlgear for voltages exceeding 1 000 V | do |

The High Voltage Switchgear and Controlgear Sectional Committee has examined the provisions of the IEC 137 ( 1984 ) 'Bushings for alternating voltages above 1 000 V' and has decided that it is acceptable for use in conjunction with this standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the results of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values ( *revised* )'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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This Indian Standard has been developed from Doc : No. ET 08 ( 5068 ).

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